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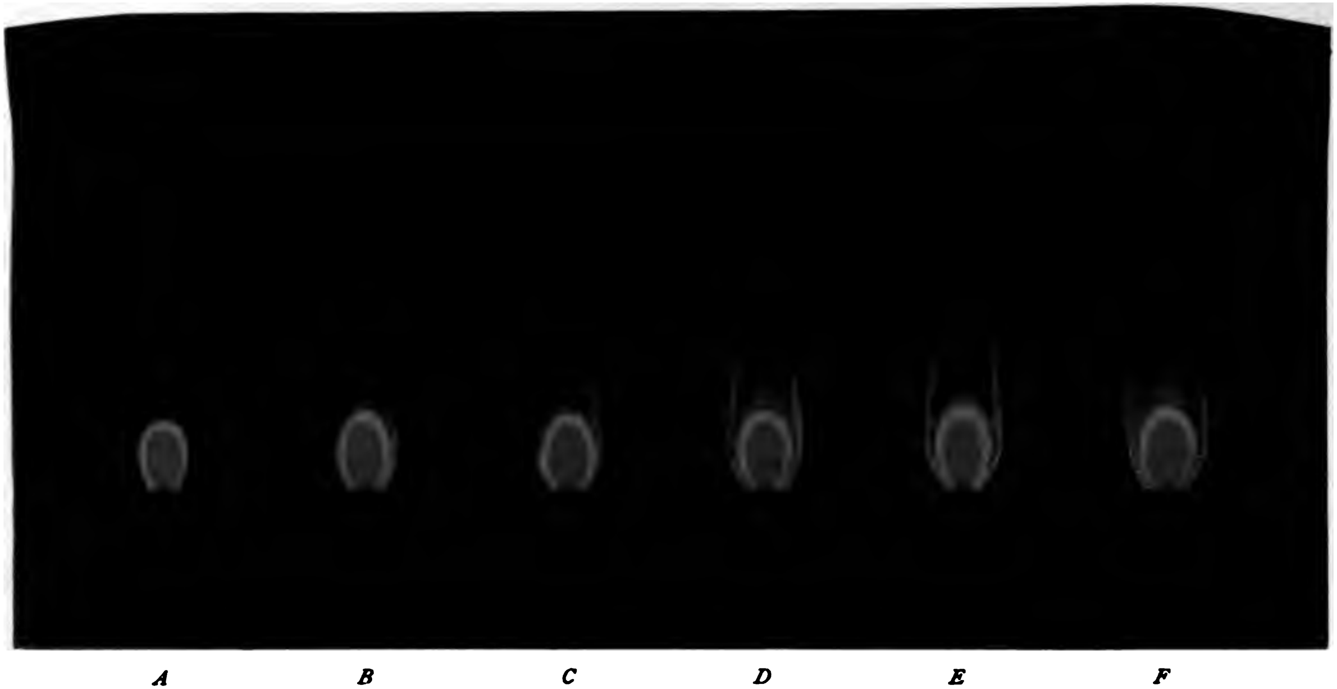

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PETROLEUM:

A Treatise on

THE GEOGRAPHICAL DISTRIBUTION AND GEOLOGICAL OCCURRENCE OF PETROLEUM AND NATURAL GAS; THE PHYSICAL AND CHEMICAL PROPERTIES, PRODUCTION, AND REFINING OF PETROLEUM AND OZOKERITE; THE CHARACTERS AND USES, TESTING, TRANSPORT, AND STORAGE OF PETROLEUM PRODUCTS; AND THE LEGISLATIVE ENACTMENTS RELATING THERETO; TOGETHER WITH A DESCRIPTION OF THE SHALE OIL AND ALLIED INDUSTRIES.

BY

BOVERTON REDWOOD,
F.R.S.E., F.I.C., Assoc. Inst. C.E.,
Vice-President of the Society of Chemical Industry, Fellow of the Chemical, Geological, and Royal Geographical Societies, Member of the American Chemical Society, Honorary Corresponding Member of the Imperial Russian Technical Society (Baku Division), Consulting Adviser to the Corporation of London under the Petroleum Acts, Chemical Adviser to the Oil Trade Section of the London Chamber of Commerce, &c.

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VOL. II.

SECTION VII.

SECTION VII.

THE SHALE OIL AND ALLIED INDUSTRIES.

ALTHOUGH the credit of having first (in 1830) investigated the properties of solid paraffin, obtained from wood-tar, belongs to Reichenbach, the existence of paraffin in petroleum had been more or less hazily known for some time previous. In 1809, Fuchs found solid hydrocarbons in the Tegernsee oils, and in 1819, Buchner separated them from these oils in comparative purity. By the latter they were described as "mountain fats," and they were identified with paraffin in 1835 by Von Kobel.[1]

Reichenbach[2] described the results of a series of experiments on the reactions between various substances and paraffin, and on account of the inert nature of the material, gave to it its present name, expressly stating, however, in doing so, that the accent should fall on the second *a*.

Paraffin was obtained by Laurent in 1830 by the distillation of bituminous shale, and in 1835, by Dumas, from coal-tar; but this substance appears to have been only regarded as a curiosity, and Lord Playfair states that prior to 1850, he never saw a piece of more than one ounce in weight. Paraffin is asserted to have been made for sale by Reichenbach's process from wood-tar by Mr. John Thom of Birkacre, before the year 1835. In the year 1833, Laurent suggested the working of the Autun shale, and products manufactured from this material were exhibited by Selligue in 1839.

In a paper by Professor F. H. Storer,[3] the credit of having first placed the manufacture of paraffin on a commercial basis, is deservedly given to Selligue, whose patent specifications, both in France and England, sufficiently clearly show that his processes of distilling bituminous schist, &c., and of purifying the distillate, had reached considerable perfection prior to 1845. His principal patents are the following:—November 14th, 1838 (No. 9,467), to which an addition was made on March 27th, 1839, and another patent, dated March 19th, 1845. Both these are French patents; but the invention comprised by the latter was also the subject of a patent taken out in England in the name of De Buisson in 1845 (No. 10,726).

In this specification, the patentee describes his distilling apparatus, which included in one case the use of superheated steam, and enumerates various qualities of distillate available for use as illuminating and lubricating oils, white crystalline paraffin suitable for candle manufacture, and sulphate af ammonia. He further describes the purification of the oils with sulphuric, hydrochloric, or nitric acid, and with alkali.

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[1] *Journ. f. prakt. Chem.*, v., 213.

[2] Schweigger's *Jahrbuch der Chemie und Physik*, 1830, xxix., 436 to 460.

[3] *Am. Journ. Sci.*, 1860, v., 30.

In its present form, however, the **shale oil industry** owes its existence to Dr. James Young of Renfrewshire. While manager of a chemical works at Liverpool his attention was, in 1847, directed by Dr. Lyon Playfair, now Lord Playfair, to a small stream of oil which flowed from the top of a coal-working at Alfreton in Derbyshire, and from this oil he succeeded in extracting, on a commercial scale, both wax and a light burning oil, as well as a heavy lubricating oil. This supply being soon exhausted, Dr. Young attempted to imitate the natural processes by which he believed the oil had been produced, by the action of gentle heat on coal, and in 1850, made his invention the subject of his celebrated patent (No. 13,292), for "obtaining paraffin oil, or an oil containing paraffin, and paraffin from bituminous coals" by slow distillation. The process was extensively carried out in the United States, under licence from Young, until crude petroleum was produced in that country in such abundance, and at so low a cost, that the distillation of bituminous minerals became unprofitable. The litigation which took place in connection with Young's patents is too well known to need description here.

During the progress of Young's experiments, a highly bituminous mineral called **Boghead coal** or **Torbanehill mineral,** was discovered, containing 60 to 70 per cent. of volatile matters, and from it he obtained from 120 to 130 gallons of crude oil per ton, other coals having only yielded 70 to 90 gallons. This mineral was worked out in 1862, and since then the oil and paraffin obtained in Scotland have been almost exclusively derived from the bituminous shales of the coal measures (first worked by Robert Bell at Broxburn in 1862), the shales of **Midlothian** and **Linlithgow** furnishing the main supply.

The output of oil shale in the United Kingdom for the year 1894 is given in the following tabular statement, and for previous years in Table XLIV.:—

	Tons.
Edinburgh,	709,141
Lanark (East),	86,881
Linlithgow,	1,168,488
[1] Stirling (East),	2,497
[1] Lanark (West),	4,250
[1] Renfrew,	11,152
Flintshire,	1,372
Stafford (North),	2,602
Total,	1,986,383

---

[1] Probably chiefly used in gas works.

TABLE XLIV.—Annual Production of Oil Shale in the United Kingdom.

SCOTLAND.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.
Total, ...	Tons. 524,095	Tons. 361,910	Tons. 424,026	Tons. 541,273	Tons. 684,118	Tons. 645,939	Tons. 712,428	Tons. 730,777	Tons. 912,171	Tons. 994,487	Tons. 1,130,729

SCOTLAND.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Ayrshire, Lanarkshire (West), and Renfrewshire,[1]	...	...	...	21,616	25,423	24,275	25,659	26,340	22,281	23,855
Edinburghshire, ...	...	...	...	582,947	701,512	664,555	734,659	884,287	802,888	758,511
Fifeshire, ...	...	...	...	72,309	154,896	131,242	144,497	132,822	109,839	5,014
Lanarkshire (East), . . .	...	...	...	17,394	17,460	13,213	55,355	77,232	104,338	94,672
Linlithgowshire, ...	...	...	...	690,817	1,152,911	1,152,386	1,218,506	1,214,325	1,032,312	1,061,034
Stirlingshire (East),[1] . .	...	...	...	5,237	...	1,319	1,807	2,926	4,418	4,756
Total, ...	1,469,649	1,741,750	1,699,144	1,390,320	2,052,202	1,986,990	2,180,483	2,337,932	2,077,076	1,947,842
Staffordshire, ...	...	...	...	...	...	...	...	...	4,663	4,036
England and Wales, . . .	49,222	28,663	29,359	21,058	24,302	27,870	31,767	23,187	...	...
Total production and value of oil shale produced in the United Kingdom, . .	1,518,871 £386,780	1,770,413 £447,302	1,728,503 £435,962	1,411,378 £355,085	2,076,504 £519,126	2,014,860 £503,715	2,212,250 £608,369	2,361,119 £707,177	... 5/ per ton	... 5/ per ton

---

[1] Principally for gas-making.

Oil shale is dark grey or black, and has a laminated or horny fracture. Its specific gravity is about 1·75, and 20 cubic feet of it weigh 1 ton.

True shales do not coke when heated to redness in a closed vessel. The proportion of mineral matter in the shale is usually about 73 per cent., but is occasionally as high as 80 per cent. The various oil shales exhibit marked differences in the yield of oil and sulphate of ammonia. The richer shales yield about 30 gallons of oil per ton of shale, and in some cases as much as 40 gallons; but the higher yield is usually obtained at the expense of the solid paraffins, and of the quality of the heavy oils. The inferior shales yield about 18 gallons of oil, but a much larger amount (from 60 to 70 lbs.) of sulphate of ammonia.

The total quantity of crude shale oil produced in Scotland during the years 1892-94, was as follows:—

1892, ...	44,238,280 gallons.
1893, ...	45,725,841 „
1894, ...	47,693,458 „

Oil shales yield members of the paraffin and olefine series rather than of the benzene group, and are thus distinguished from the true coal shales.

The discovery of workable seams of oil shale in the early days of the Scottish oil industry was not characterised by the excitement which prevailed during the development of the older oil fields of the United States, but was, nevertheless, not unattended by features of interest. The author has in his possession a block of shale, carved into the form of a book, of which the following particulars were supplied to him by Mr. Stewart S. Robertson:—

"Some forty years ago, my father had one morning a visit from a notorious poacher, who undertook, on payment of one sovereign and the promise of fifty more, to show him something, and never again to poach on our property. The sovereign was paid, and I was deputed to accompany him. On arriving at a certain point where a burn runs between high steep banks, he began picking up bits of what he told me was shale, and showed me a part of the burn which flowed over a smooth black surface of shale. At this time everybody was going shale mad, as Young had just commenced his now well-known works at Addiewell, about 3½ or 4 miles, as the crow flies, from Tarbrax, the place of which I am writing. The poacher received his £50, and never troubled us again. The next day I returned to the spot with a man provided with the necessary tools, and we soon dug a hole 2 or 3 feet deep, and took out some pieces of the shale, from one of which the 'book' you have was made. We had numerous offers to lease the land, among them one from Young himself, but my father selected Mr. Fernie as his tenant for 719 acres. Mr. Fernie at once commenced erecting works, but the difficulty of transporting machinery was very great, the site being on a wild moor, and before the works were quite completed Mr. Fernie died. Operations were continued by the executors, the Caledonian Railway made a branch line 4 miles long on to the property, and eventually the Caledonian Oil Company, Limited, became, and now are, the tenants."

The following table gives the names of the companies engaged in the Scottish oil industry, the year of formation, and the amount of paid-up capital and debentures, as at the date specified :—

Name.	Year (about).	Capital paid up and Debentures.
Young's Paraffin Co., . .	1854	£753,770 0 0 as at 30th April, 1894.
Stanrigg Oil Co., . . .	1865	50,000 0 0 as in 1891.[3]
Oakbank Oil Co., . . .	1868	67,500 0 0 as at 31st March, 1895.
[1]Dalmeny Oil Co., . . .	1871	18,900 0 0 as at 31st Oct., 1894.
Broxburn Oil Co., . . .	1877	299,750 0 0 as at 4th April, 1894.
Burntisland Oil Co., . .	1881	261,359 0 0 as at 31st March, 1892.
Clippens Oil Co., . . .	1882	227,159 10 0 as at 30th Sept., 1894.
Westlothian Oil Co., . .	1883	97,098 10 0 as at 31st March, 1891.
Pumpherston Oil Co., . .	1888	213,310 0 0 as at 30th April, 1894.
[1]Holms Oil Co., ...	1884	40,000 0 0 as at 30th April, 1894.
Linlithgow Oil Co., . . .	1884	174,807 10 0 as at 31st March, 1894.
Hermand Oil Co., . . .	1885	274,326 15 0 as at 31st March, 1893.
[1]James Ross & Co., . . .	1885	79,000 0 0 as in 1891.[3]
[2]Caledonian Mineral Oil Co.,	1889	107,450 0 0 as at 31st May, 1892.
		£2,664,431 5 0

Of these companies, the Westlothian is no longer in existence, and neither the Burntisland nor the Hermand (which acquired the refinery of the Walkinshaw Oil Company) is carrying on the manufacture.

Attempts have been made to establish an industry in Ireland by the manufacture of oils and paraffin from peat. As far back as 1849, Mr. Rees Reece and Sir Robert Kane conducted experiments with this object in view, and in 1850, paraffin was commercially made from this source.

An account of the **Kimmeridge** (Dorsetshire) **shale** will be found at the end of this section.

In **New South Wales**, a so-called "**kerosene shale**," which, however, Professor Liversidge states, is more of the nature of a cannel coal or *torbanite*, and does not possess the properties of a shale, is now produced at four mines, and is distilled by two companies. One company is situated at Botany Bay, and is known as the New South Wales Shale and Oil Company, its former name having been the Western Kerosene Oil Company. It distils weekly about 400 tons of shale obtained from Hartley Vale, near the Blue Mountains, on the western line. The other company — the Australian Kerosene Shale and Oil Company — distils weekly about 200 tons of shale from Joadja Creek, near Mitteagong, about 80 miles south of Sydney. The following tables show the production of these shales from 1865, and the results of analyses made in 1889 for the Department of Mines of New South Wales:—

---

[1] Manufactures crude oil, but does not refine.

[2] This Company purchased the business of the Lanark Oil Co.

[3] Estimated amount.

TABLE XLV.—KEROSENE SHALE PRODUCED IN NEW SOUTH WALES FROM 1865 TO 1889.

Year.	Quantity.	Average Price per ton.			Total Value.		
	Tons.	£	S.	D.	£	S.	D.
1865	570	4	2	5·47	2,350	0	0
1866	2,770	2	18	10·48	8,150	0	0
1867	4,079	3	14	9·21	15,249	0	0
1868	16,952	2	17	7·11	48,816	0	0
1869	7,500	2	10	0·00	18,750	0	0
1870	8,580	3	4	3·18	27,570	0	0
1871	14,700	2	6	3·91	34,050	0	0
1872	11,040	2	11	11·91	28,700	0	0
1873	17,850	2	16	6·55	50,475	0	0
1874	12,100	2	5	1·48	27,300	0	0
1875	6,197	2	10	2·22	15,500	0	0
1876	15,998	3	0	0·00	47,994	0	0
1877	18,963	2	9	0·81	46,524	0	0
1878	24,371	2	6	11·40	57,211	0	0
1879	32,519	2	1	1·96	66,930	10	0
1880	19,201	2	6	7·03	44,724	15	0
1881	27,894	1	9	2·59	40,748	0	0
1882	48,065	1	15	0·00	84,114	0	0
1883	49,250	1	16	10·77	90,861	10	0
1884	31,618	2	5	7·86	72,176	0	0
1885	27,462	2	8	11·62	67,239	0	0
1886	43,563	2	5	10·79	99,976	0	0
1887	40,010	2	3	10·43	87,761	0	0
1888	34,869	2	2	2·66	73,612	0	0
1889	40,561	1	18	3·55	77,666	15	0
...	556,682	2	4	4·20	1,234,448	10	0

TABLE XLVI.—ANALYSES OF KEROSENE SHALES OF NEW SOUTH WALES.

Locality.	Hygroscopic Moisture.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.	Sulphur.	Coke.	Sp. Gr.	Remarks.
Capertee, . .	1·02	74·70	14·86	9·42	1·304	nil.	1·104	No true coke formed.
,, . .	0·76	71·34	17·06	10·84	0·988	,,	1·130	,, ,, ,,
,, . .	...	...	...	12·37	...	...	...	Ash estimated only.
,, . .	...	...	...	12·45	...	...	...	
Dungaree, . .	...	...	...	54·41	...	...	...	
,, . .	0·71	57·61	10·85	30·83	0·578	nil.	1·26	Ash, light grey.
Gough Harbour, .	0·40	77·38	8·27	13·95	0·789	,,	1·10	
Hartley (near), .	...	53·55	18·2	28·25	...	...	...	...
Jervis Bay, . .	0·20	44·46	12·87	42·47	...	...	...	...
Katoomba, . .	0·86	46·39	32·05	20·70	0·576	52·75	1·251	A dull coke formed, fairly hard.
,, . .	1·16	56·79	13·73	28·32	0·88	nil.	1·264	No true coke formed; ash, grey.
,, . .	0·66	67·52	10·68	21·14	1·02	,,	1·02	,, ,, ,,
,, . .	0·87	62·84	12·55	23·74	0·840	,,	1·180	Ash, grey.
Megalong, . .	0·58	62·29	12·35	24·78	nil.	,,	1·214	...
,, . .	1·52	56·96	14·68	26·84	0·83	,,	1·323	No true coke formed; ash, grey.
,, . .	0·65	60·55	12·68	26·12	nil.	,,	1·226	...
Mudgee District, .	0·35	66·98	12·01	20·66	0·43	,,	1·195	No true coke formed; ash, grey.
,, .	0·89	76·42	16·62	6·07	0·854	,,	1·06	Ash, bright red; residue firmly coked
Penrith (near), .	0·51	50·29	8·90	40·30	0·342	,,	1·291	Ash, white.
Picton ,, .	1·54	26·89	25·75	45·82	...	...	...	Ash, grey; no coke.
,, ,, .	1·52	22·94	26·79	48·75	...	...	...	,, ,,
Port Stephens (Morna Point),	1·10	49·45	14·22	35·23	...	...	...	Ash, bulky, slate coloured; no true coke.
Thirlmere (14 miles from),	1·75	40·30	9·70	48·25	0·686	nil.	1·478	No true coke; ash, slate colour.
Wentworth Falls,	0·39	65·91	7·6	26·10	0·961	,,	1·13	Ash almost white.
Westmoreland (County of),	0·78	50·12	7·04	42·06	0·357	,,	1·356	No true coke; ash, grey

TABLE XLVIa.—ANALYSES OF NEW ZEALAND SHALES.

Percentage Composition.						Relative percentage of Volatile Matters.	Relative percentage of Fixed Carbon.
Locality.	Volatile Matters.	Fixed Carbon.	Water.	Ash.	Sulphur.		
D'Urville Island, . .	81·79	7·98	0·69	9·54	traces	91·11	8·89
Mongonui, .	75·20	9·30	1·80	13·70	,,	88·99	11·01
Chatham Islands, .	66·43	20·41	4·61	8·55	,,	76·49	23·51
,, ,,	64·67	19·87	7·13	8·33	,,	76·49	23·51

In **New Zealand**, bituminous shales occur to a small extent in the upper portions of the coal measures. Specimens have been examined by the Government geologist from D'Urville Island, in Cook Strait; Monongui and Waiapu, in Auckland; Kaikorai and Blueskin, in Otago; and Orepuki, in Southland. A company has been formed to work the shale of Orepuki, in the hope of obtaining a bonus of £5,000 which has been offered by the Wellington Government for the first 100,000 gallons of oil manufactured in the Colony.

In a recent article,[1] M. G. Chesneau has given a very full description of the **French Shale Oil Industry.**[2] The principal deposits are those of Autun and Buxières-les-Mines, both of which have been continuously worked, the former since 1862, and the latter since 1858. It was with the Autun shales that Selligue obtained the results referred to at the beginning of this section. There are also workings in the Var, the Puy de Dôme, and the Basses Alpes, but they are insignificant as compared with those of Autun and Buxières.

The Boson shale field in the department of the Var lies about five miles north-east of the Frejus station of the Marseilles and Nice railway. Works were erected here many years ago and were for some

TABLE XLVII.—CONCESSIONS AND METHOD OF WORKING IN THE DISTRICTS OF BUXIÈRES AND AUTUN.

Concessions.	Proprietors.	Nature of Works.
Buxières.		
1. Buxières - la-Grue and La Courolle,	M. Duchet,	Underground, for shale and coal. A pit and a tunnel in the hillside. Works for distilling shale and refining crude oil.
2. Les Clamores,	MM. Rondeleux & Cie.,	Underground, a pit for shale and coal. Distilling and refining works. There is also a tile works.
3. Saint-Hilaire,	M. le comte de Chateaubriant,	Underground, a pit for shale and coal. Distilling and refining works.
Autun.		
[3]Les Telots and Surmoulin,	Société Lyonnaise,	Underground workings (pit) for shale and boghead. Distilling plant.
[3]Margenne,	...	The same, but for shale only.
[3]Ravelon,	..	,, ,, ,,
[3]Igornay,	...	,, ,, ,,
Muse,	M. Aymard,	Underground shale workings. The shale is distilled and the crude oil sold to the Cie. Lyonnaise.
Le Ruet,	M. J. Ragot,	Underground (pit), for shale. Distilling and refining plant.
La Comaille,	MM. Rondeleux & Cie.,	,, ,, ,,

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[1] *Ann. des Mines*, 1893, iii., 617 to 674.

[2] Other valuable articles on this subject are those of Choisson (Schistes bitumineux d'Autun), and of Tournaire (Industrie des huiles de Schiste dans l'Autunois), in the *Ann. des Mines*, 1871, Sixth Series, xx., 347 and 474.

[3] N.B.—The oils from these four works are refined in the same works at Saint-Leger.

time in operation. The shale, which is said to resemble Boghead, appears to have yielded about 50 gallons to the ton, of crude oil, from which the following products were obtained:—

Burning oil and spirit,	25 gallons.
Lubricating oil,	10 ,,
Paraffin scale,	2¼ ,,

TABLE XLVIII.—Production of Shale Oil at Autun and Buxières during 1890.

Mines and Works.	Production of Shale in 1890.	Number of Retorts.	Crude Oil obtained per Hectolitre of Shale.	Density of the Crude Oil.	Production of Crude Oil.	Number of Refining Stills.	Number of Hands Employed. In Extracting Shale.	Number of Hands Employed. In Distillation and Refining.
Autun—								
Société Lyonnaise:—	Cubic Metres.		Litres.		Hecto-litres.			
Les Telots, . .	25,572(*a*)	64	4·50	0·875	14,733	...	162	78
Margenne, . .	6,000	6	4·50		1,500	...	15	40
Ravelon, . .	27,620	52	5·50		14,186	...	55	35
Igornay, . .	29,100	87	4·50	0·860	13,712	...	75	40
St. Leger, . .	...	...	...	...	...	20	...	45
Muse, . . .	13,564	49	5·40	0·872	7,443	...	23	12
Le Ruet, . . .	20,000	36	5·25	0·862	10,500	10	34	27
La Comaille, . .	24,000	50	5·75	0·870	13,800	14	55	65
Totals and averages,	145,856	344	5·05	0·878	75,874	44	419	342
Buxières—								
Les Plamores, . .	19,682	36	5·80	0·893	11,600	19	62	30
Buxières - la - Grue and la Courolle, .	28,000	60	5·40	0·897	20,000	14	120	50
Saint-Hilaire, . .	22,613	36	6·25	0·877	14,000	8	35	43
Totals and averages,	70,295(*b*)	132	5·88	0·889	45,600	41	217(*c*)	123
Grand total, .	216,151(*b*)	476	5·43	0·883	121,474	85	636(*c*)	465

Observations.

(*a*) In addition to 8,600 tons of boghead.
(*b*) ,, 39,450 tons of coal.
(*c*) ,, 166 hands employed in the coal getting.

At Buxières, the measures are blackish shales and sandstones, and consist in an upward direction of (1) coal; (2) bituminous shale; and (3) flint, limestone, and bituminous shale. At Autun, the shales extend over an area of 18,000 hectares (1 hectare equals 2·47 acres), and comprise nine proven seams, of which seven are worked. They are usually from 2 to 2½ metres in thickness, but the upper seam, which is worked at the Telots, has a thickness of only about 1 metre. It, however, includes a seam, 25 centimetres in thickness, of Boghead coal, which gives it value. Tables XLVII. and XLVIII. show the concessions and methods of working at Autun and Buxières, and give various other particulars of the industry.

Large deposits of shale occur in **Servia**, near the station of Alexinatz, on the Servian railway. The principal shale seam appears to consist of "leaf shale" (6 metres), and "sandy shale" (26 metres), with bands of poorer shale above and below. In a practical trial made by one of the Scottish oil companies, this shale is stated to have yielded per ton, from 43½ to 45½ gallons of oil having a solidifying-point of 90° F. Analytical examination is said to have shown that the crude oil would yield per 100 gallons:—

	Specific Gravity.	Gallons.
Burning oil,	0·810 to 0·820	30·0
Intermediate oil,	0·840 to 0·865	4·5
Lubricating oil,	0 880 to 0·885	15·5
Paraffin scale, hard and soft,	...	14·3

Extensive deposits of oil shale are stated to occur in the **Ronda** district in Southern Spain.

The production of mineral oils and paraffin by the distillation of **lignite** is carried on in **Saxony**. The mineral worked is a peculiar earthy lignite occurring within a small portion of the Saxon Thuringian brown-coal formation, between Weissenfels and Zeitz.

The geological occurrence and mining of oil shale in Scotland have been very fully treated by Mr. R. T. Moore, from whose description[1] the following account is largely derived.

Geological Formation.—The Scottish shale oil industry depends almost entirely on the shales of the Calciferous sandstone series, lying between the Carboniferous limestone and the Old Red sandstone. They occupy a large area in the centre of Scotland, running south-west from St. Andrews and Dunbar to Ardrossan in a belt 30 to 40 miles wide, but so far, oil shales have only been found near West Calder, Uphall, Queensferry, Loanhead, and Burntisland, a distance between extremes, of 24 miles. The beds occur mostly in small basins, cropping up to the surface on all sides, with a small flat portion in the centre of the basin, the outcrops being in some cases cut off by large faults. One of the largest continuous areas of shale is at Pentland, the levels being 2 miles long without important faults.

The thickness of shale-bearing strata proved is about 3,000 feet, the leading feature being the Camps or Burdiehouse (fresh-water) limestone, sometimes 40 feet thick, above and below which are found well-known shale seams. The following principal seams have been recognised in the descending order given:—

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[1] *Trans. Fed. Inst. Mining Eng.*, 1893, iv., 36.

1. The Dam or Raeburn shale.
2. The Mungle or Stewart shale.
3. The Grey shale.
4. The Fell shale.
5. The Broxburn shales.
6. The Dunnet shales.
7. The Barracks shale.
8. The Pumpherston shales.

The **Dam shale** averages from 2½ to 3 feet in thickness, and has only been worked to a limited extent.

The **Mungle shale**, which averages about 2½ feet in thickness, was formerly worked in the West Calder district. It is separated from the Grey shale by the "*two-foot coal*," which was formerly worked as cannel at Drumcross, near Bathgate.

The **Grey shale** is worked at Addiewell, and lies above the Houston coal, which consists of several thin coal seams, formerly, but not very successfully, worked, at West Calder, Broxburn, and Ochiltree.

The important **Fell shale**, which is the richest of the Scotch oil shales, is worked at Tarbrax, Addiewell, Breich, Seafield, Hermand, and Pentland. It produces from 36 to 40 gallons of crude oil, and yields from 11 to 14 lbs. of ammonium sulphate to the Henderson retort, and 25 to 35 lbs. to the Young and Beilby retort, per ton.

Next come the **Wee**, the **Big**, the **Wild**, and the **Curly shale**, followed by the **Broxburn shale**, which averages 5½ feet in thickness, and is worked at Addiewell, Seafield, Hermand, Oakbank, Broxburn, Hopetown, Linlithgow, Philipstown, and Pentland. It produces 28 to 33 gallons of crude oil, and yields 16 to 20 lbs. and 26 to 32 lbs. of ammonium sulphate to the Henderson and Young and Beilby retorts respectively. It is underlain by the **Lower Wild shale.**

The **Dunnet shale** is from 6 feet to 16 feet in thickness. It is worked at West Calder, Oakbank, Pentland, and Burntisland. It yields from 15 to 30 gallons of crude oil, and overlies the Lower Dunnet shale, which is worked at Oakbank only.

The **Barracks shale** was formerly worked to a small extent at Deans, near Bathgate, and at Linlithgow, and has an average thickness of about 10 feet. Beneath it lie the **Camps** or **Burdiehouse limestone**, and then come the **Pumpherston shales**, which comprise the **Jubilee shale** about 8 feet thick, the **Maybrick shale** about 6 feet, the **Curly shale** about 6½ feet, the **Big plain shale** about 8½ feet, and the **Wee plain shale** about 4½ feet in thickness. All these shales are worked at Holmes and Pumpherston, as well as at the Roman Camp Works of the Broxburn Oil Company.

The **Curly shale** yields 19 gallons of crude oil per ton, and from 60 to 70 lbs. of sulphate of ammonia to the Young and Beilby retort. On the average the Pumpherston shales yield 16 to 22 gallons of crude oil per ton, together with 25 to 35 lbs. of sulphate of ammonia to the old form of the Henderson retort, and 50 to 60 lbs. to the Young and Beilby retort.

The "blaes" between the various Pumpherston shales yield a large quantity of sulphate of ammonia, and are sometimes distilled along with the shales.

The seams vary in thickness and quality in different districts. Thus, the Broxburn shale, which yields over 30 gallons of oil at

Broxburn and Oakbank, only produces 19 gallons at Linlithgow. The shales accompanying this seam, viz., the Big shale, the Curly shale, and the Wild shale, are all worked at Oakbank, but are thin and unworkable at Linlithgow. The two seams found below the Dunnet at Oakbank have not, so far, been recognised at Pentland.

The distance between the seams also varies greatly; the distance, for example, between the Dunnet shale and the Burdiehouse limestone being only 20 fathoms at Pentland, and over 100 fathoms at Oakbank. The variations are greater than in the coal seams, and this has caused many disappointments, the best known seams having been at their best where first opened up, and subsequent seams showing no improvement. Generally, the upper seams, down to the Broxburn shales, contain more oil than the lower, the latter being richer in ammonia. This last is a special feature of the Pumpherston shales.

So far, the seams have not been worked under the outcrop of the Carboniferous limestone, the nearest being to within 300 yards, at Pentland (where the shales dip at an inclination of 1 in 2), and the deepest workings, 200 fathoms from the surface. It is not easy to form an idea whether they exist under this formation, or how far they occur in other parts of the Calciferous sandstone, the few borings in the east of Fifeshire, Haddingtonshire, and Ayrshire having been unsuccessful. At Lesmahagow, and in parts of Ayrshire, the Calciferous sandstones are wanting, the Old Red sandstone lying directly below the Carboniferous limestone.

Mining or Winning Oil Shale.—The shale is mined by the pillar and stall system when the seams are over 4 feet in thickness, the pillars being left large enough to be taken out in a second working. Seams under 4 feet are worked by the long-wall system. The shale is blasted down by gunpowder. It is all passed over a 1-inch riddle, and the smalls are left underground. The tubs are drawn up by coupled direct-acting engines, in trains of eight to twelve. Each carries from 7 to 14 cwts. The water in the shale deposits is usually not great, and seldom exceeds 300 gallons per minute. It is often pumped up by the Moore hydraulic pump, but at Oakbank, where the influx is sometimes as much as 1,200 gallons of water per minute, there is a vertical pit 70 fathoms deep, with a grasshopper beam engine, and 28-inch plungers. The pumping is attended with some difficulty, direct rods from the surface being liable to breakage, while the heat from steam pumps injures the roof and floor of the workings. Although shales evolve fire damp, all the mines are worked with naked lights, a very perfect ventilation being maintained by fans.

The cost of production varies between 4s. and 6s. per ton delivered at the works. Lordships or royalties vary from 3d. to 10d. per ton of shale. If levied on the crude oil, they are usually one-third of a penny per gallon; if on the refined product, one-fortieth to one-thirtieth of the price.

The mines are frequently close to the works, in which case the tubs are drawn in by chain haulage or otherwise. The greatest distance between mine and works does not exceed 4 or 5 miles. Before being retorted, the shale is passed through a toothed breaker, which reduces it to flat pieces about 6 inches square, as much as 600 tons being treated daily by each breaker. It is then raised by an elevator to iron tubs of 10 cwts. capacity, which run along rails and discharge into the tops of the retorts.

Distilling Shale.—For much valuable information relative to the distillation of shale, and the refining of the products, the author is indebted to Mr. John Wishart, of the Oakbank Oil Company. At the beginning of the shale oil industry, the distillation was conducted in horizontal retorts, like those now used for coal gas, and the heavy oils and paraffin obtained in the refining of the crude oil were burned. After it was found that the solid paraffin was of value, the vertical retort was introduced, as the dissociation of this product is thereby minimised, and steam was employed to carry the oil vapours from the retort. The condensed water was also utilised as a source of ammonium sulphate.

The next improvement consisted in distilling under a reduced pressure, and this was followed by the invention in 1871, by William Young, of an arrangement in which the exhausted shale was employed as a heating agent. Young, however, attempted to produce this result in a prolongation of the retort in which distillation was progressing, and it was found that the product thus became contaminated with tar. His invention was soon superseded by that of Henderson, in which the spent shale was allowed to drop from the retort into the furnace, where it served, in its already heated condition, as fuel. At a later date, the retort jointly invented by Young and Beilby came into general use, and that in turn may not improbably be replaced by the new Henderson retort, or by the retort now being tested by the Pumpherston Oil Company.

The constant improvement in the distilling apparatus, described in detail in the following pages, has resulted in so great a reduction in the cost of the products, that the Scottish industry has hitherto been able to compete against imported oils and paraffin obtained from petroleum. The various economies introduced are stated to have resulted in the reduction of the cost of finished oil (after crediting the value of the sulphate of ammonia) to 2½d. per gallon, which is about one-sixth of the cost thirty years ago.

In the earliest system of distillation, the shale was heated, as already stated, in horizontal cast-iron retorts resembling those then used for coal-gas manufacture, the retorts being discharged after the volatile constituents had been driven off, and re-charged.

The difficulty of regulating the heat in this form of retort led to the introduction of a system devised by Hompesh, in which a horizontal retort heated to redness only at one end was employed. The shale was introduced at the cool end and was gradually driven by a screw towards the heated end, where it was discharged in a spent condition. This system was adopted by Young and Meldrum, but was found unsatisfactory, and was soon superseded by the use of vertical retorts, the introduction of which is attributed by the late Dr. A. C. Kirk to Dr. Price. An arrangement for the employment of vertical retorts on what is known as the continuous system, is shown in Figs. 137 to 139. The retorts were of circular (2 feet in diameter) or of oval section (2 feet by 1 foot 4 inches) and 8 or 10 feet long. Six or eight of these were arranged in a chamber with an arched furnace in the centre, and were charged, without allowing escape of vapour, by means of hoppers at the top. A portion of the exhausted shale was withdrawn every hour from the lower end of the retorts through a trough of water, forming a seal, so that the charge descended gradually and was slowly raised in temperature.

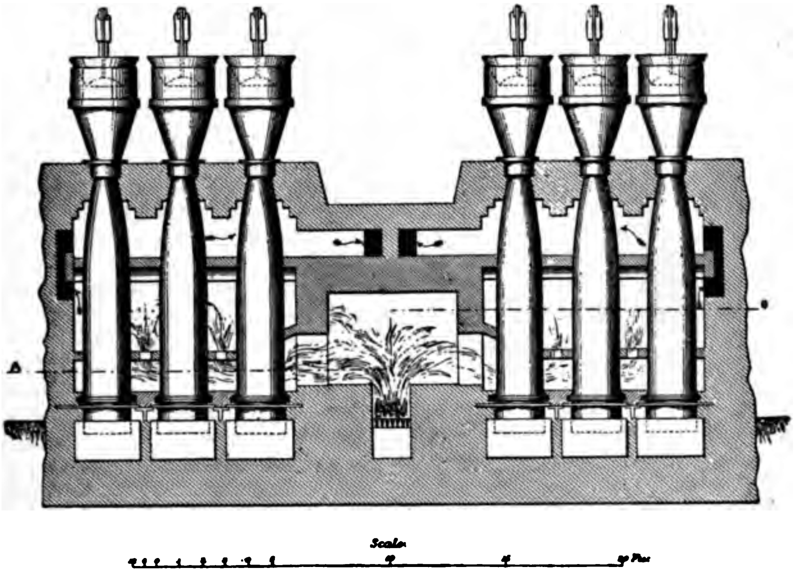

Fig. 137.

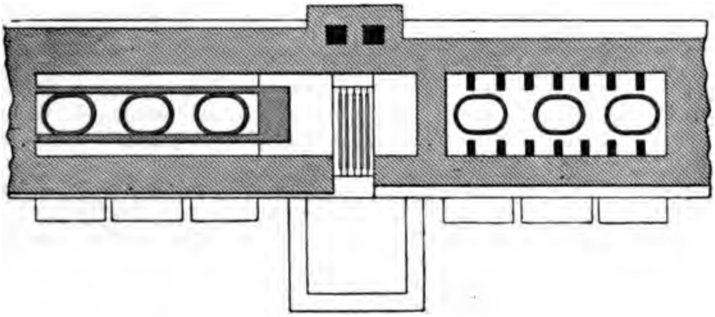

Fig. 138.

The heat employed was a dull red, and the lower portion of the retort was the hottest. A jet of steam was introduced at the bottom of the retorts, and the products passed from the upper part to the condensers.

The use of steam appears to have been first suggested by Selligue,[1] and is said to have given with the **Bathgate retort**, in 1861, an increase in the yield of oil from Boghead coal, from 90 or 100 gallons to over 120 gallons per ton.

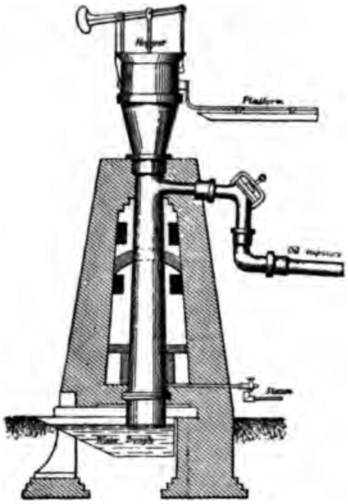

Fig. 139.

In 1879-80 Young and Beilby found that if the shale, after complete distillation of the volatile matter, were submitted to the continued action of steam at a high temperature, an increased amount of the nitrogen of the shale was obtained as ammonia.

For some time after the introduction of the continuous system, intermittent distillation in horizontal retorts was still carried on by many makers, as the "cracking" of the heavier oils in such retorts gave large quantities of light burning oils, which required little refining, and were then in the greatest demand. A rival to the continuous system was introduced in 1867, in the **intermittent retort** (Fig. 140), patented by William Young and Peter Brash.[2] This was set vertically, and the bottom was protected from the fire, while the sides were heated by the gases from the furnace. The retort was joined at the bottom to an outer casing, but was open at the top. Part of the incondensable gases evolved from the shale were passed into the space between the retort and its casing, and having become further heated, were drawn into the retort and passed downwards through the shale, carrying the oil vapours to the condensers. When first introduced, this retort is said to have given better results than the continuous retort, but it was soon superseded by improvement made in the latter form.

In the earlier form of **Henderson retort** (Fig. 141), patented in 1873 (No. 1,327), the spent shale, the carbon content of which amounts to about 9 to 14 per cent., is utilised as fuel. The retorts, which are set in a group of four in a chamber above the furnace, are of oblong cross section, 15 feet in length, and of a capacity of about 18 cwts. The furnace has an arched roof, along the centre of which are apertures for the passage of the furnace gases into the chamber above, these gases being first led upwards by vertical flue walls or screens, and finally passing from the chamber through flues, into the chimney.

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[1] See patent taken out in England by De Buisson in 1845 (No. 10,726).

[2] Patent, No. 650, 1867.

The lower end of the retort is slightly bevelled and projects into

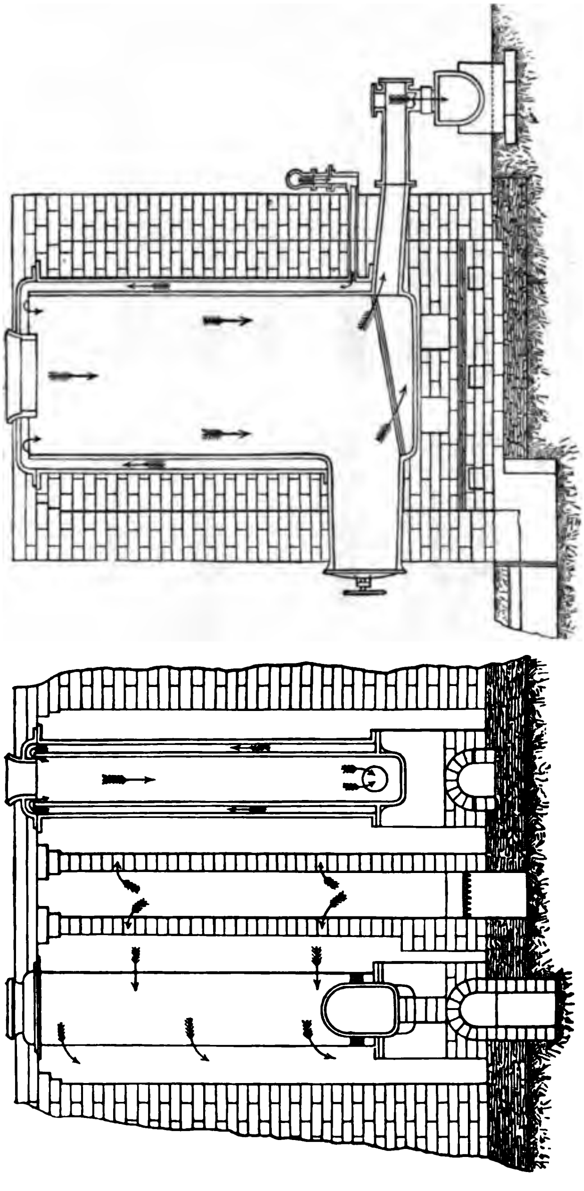

Fig. 140.

the furnace as shown, through an iron framing fitted with an iron valve, 9, lined with fireclay and normally protecting the bottom door, 7, of the retort and its fittings. A light, removable, malleable iron lever, 8, with a horizontal spindle, turns in bearings in the casing containing the framing, and serves for opening or closing the door, 7.

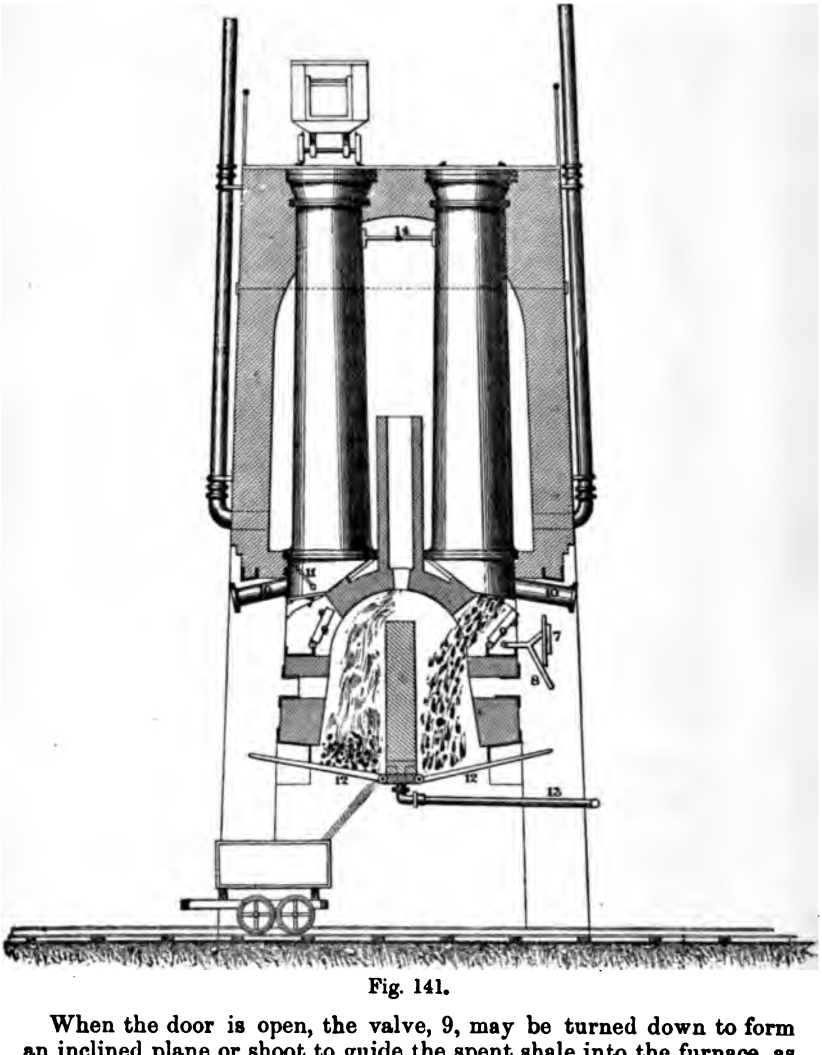

Fig. 141.

When the door is open, the valve, 9, may be turned down to form an inclined plane or shoot to guide the spent shale into the furnace, as shown to the right of the figure. A hinged grating, 11, keeps the shale away from the colder outer corner of the retort bottom, and when the door, 7, is removed, prevents the shale from descending until the valve, 9, is turned outwards. The combustion of the spent shale is assisted by the introduction of a little coal into the furnace, and the incondensable gas from the retorts is also supplied through a pipe, 13. The bottom plates, 12, of the furnace may be turned downwards to discharge the ashes into bogies.

The retorts are charged in rotation as follows:—When a sufficient temperature has been attained in the chamber containing them, one retort is charged from the top, and in four hours, the one diagonally opposite to it is charged. After eight hours, the one next to the first is charged, and after twelve hours, the fourth. Up to the sixteenth hour only ordinary fuel is used in the furnace, but the spent shale from the first retort is then discharged into the furnace. The other retorts are similarly discharged in the above order at intervals of four hours, each being at once recharged. The shale is black when discharged, but it soon glows brightly. Owing to the small amount of carbon in the spent shale, only a slow draught is kept up.

The outlet, 10, for the oil vapours is at the lower and less heated end of the retorts, and steam, which has been superheated by passage through pipes arranged along one side of the retort chamber, is blown in copiously through pipes, 14, to aid in the uniform heating of the shale and to continuously remove the oil vapours, dissociation from overheating being thus minimised. It is believed that a temperature of about 800° F. produces the best results.

The system patented jointly by Young and Beilby[1] was the outcome of independent patents taken out by these inventors.[2]

In this system, the "Pentland" composite retort (Fig. 142), which has an upper part, A, A1, of iron, and a lower part, A2, of firebrick, is employed. The retorts are arranged back to back, and 80 to 100 in a bench, in groups of four, each group being surmounted by a large casting, A6, known as a "jumbo," which has four lids for filling, and a pipe for carrying away the gases to the main. This casing or hopper contains sufficient shale to charge the four retorts. At the lower end, each retort is closed by a faced mouthpiece and steel door.

Heat is supplied by a gas producer (Fig. 143), consisting of a brick retort, B2, closed above by a door, B6, and having an exit pipe, B4, communicating with a main, B5, passing to the condensers. The retort terminates below in an ordinary fireplace and ashpit with regulating doors and dampers. The retort is filled with small coal or "dross," and, as its upper part is kept at a red heat by the fire gases which pass through flues around it, the coal there is distilled, and the gas and vapour evolved pass through the exit pipe to the condensers.

As the coke, which is thus formed, descends in the retort, it meets a current of steam from a superheater, S, and is partly decomposed, with production of water-gas and ammonia, which pass off with the other volatile products. The unburned coke which finally reaches the firebars, is burned to carbon monoxide by a carefully regulated air current, and the producer gas so obtained is led away by ports at the lower end of the retort, and is burned in the flues surrounding the shale retorts. The water-gas produced is also burned around these retorts after its condensable constituents have been removed. The gas from the shale distillation is almost invariably used as fuel by admitting it from a main, O, so that it is burned in flues, F6, by air supplied in regulated amount through pipes, F2, where it becomes heated by the flue gases, before admixture with the gas. For each eight shale retorts, there are two retorts, B2. The iron upper part of the shale retorts is heated to dull redness, and the lower fire-brick portion to a bright red heat.

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[1] Patents, No. 1,377, 1882, and No. 5,084, 1882.

[2] See patents of Young, No. 1,578, 1880, and No. 1,587, 1881; and of Beilby, Nos. 2,169 and 4,284, 1881.

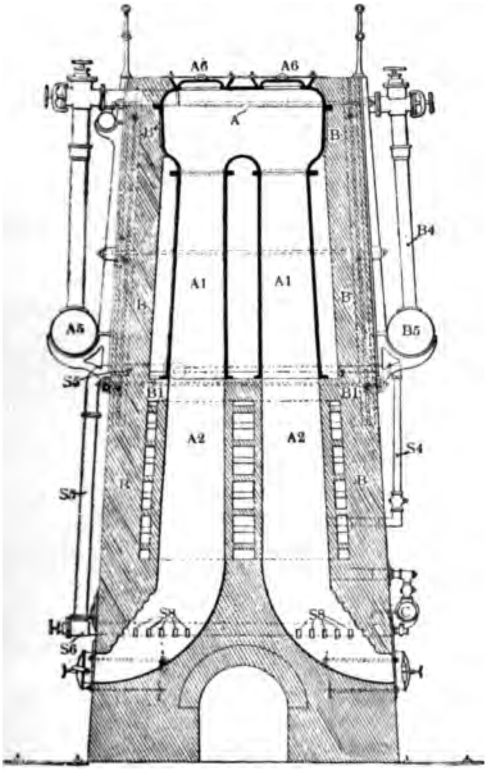


Fig. 142.

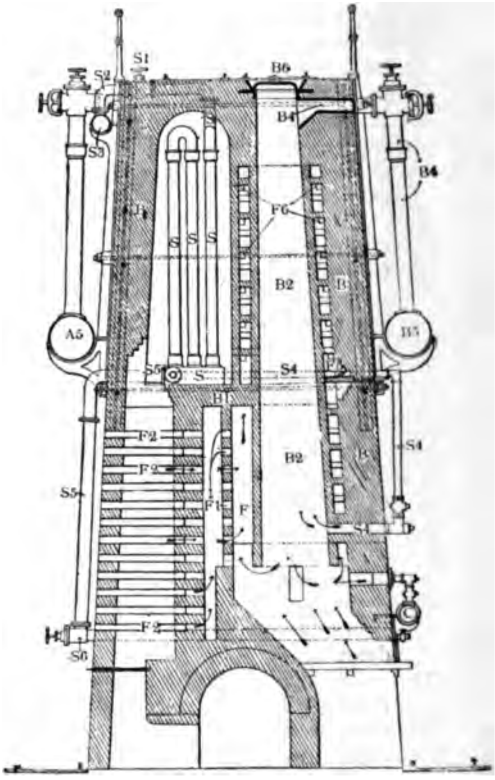
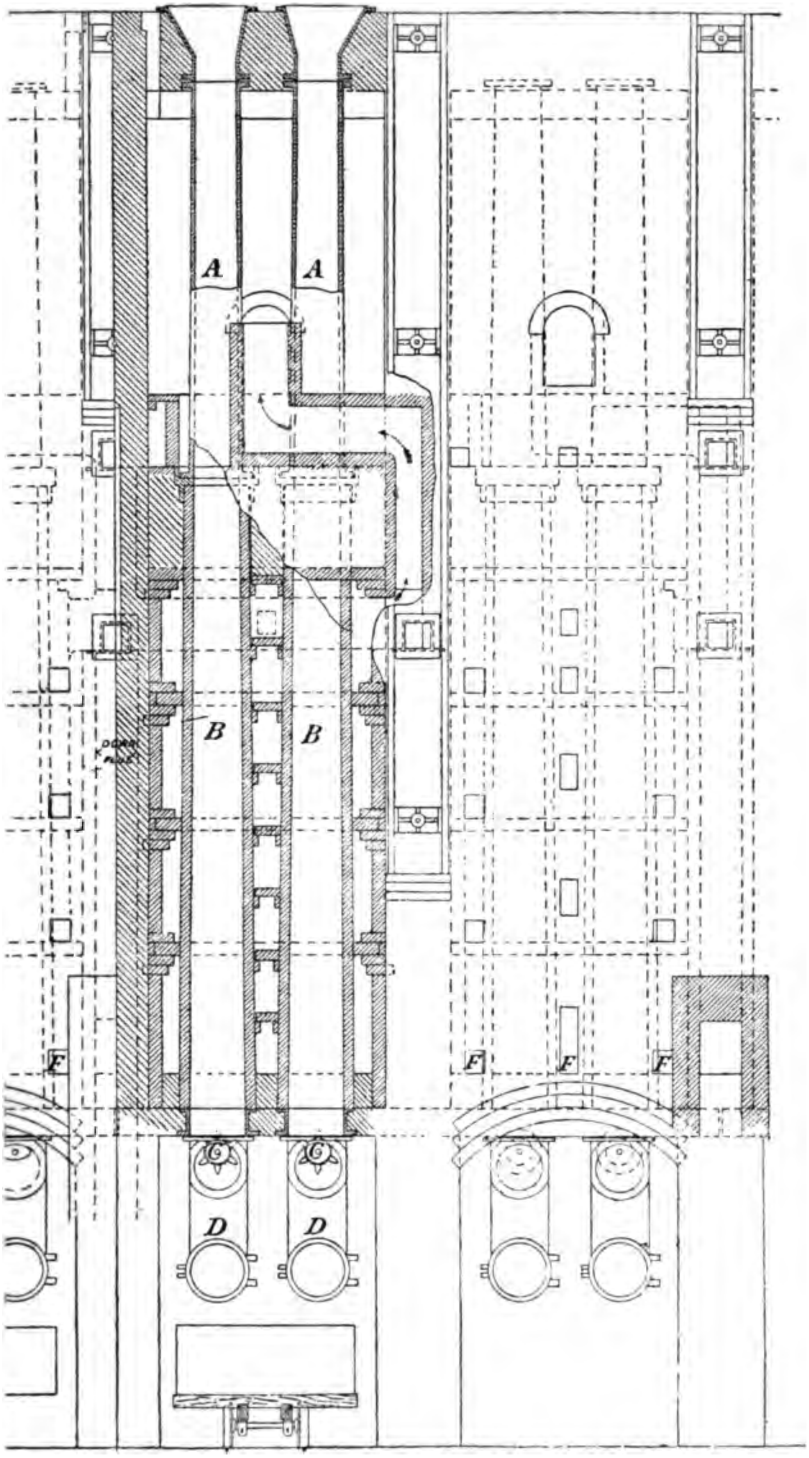


Fig. 143.

In commencing distillation of the shale, the lower portion of the retort is first heated and filled with spent shale, after which the upper portion is charged with the raw shale to the hopper. Steam is then



RT (*New Form*).

passed into the lower part of the retort, about 2 feet from the bottom, and, becoming superheated in traversing the red-hot, spent shale, passes through the raw material, which is further heated, externally, by the flue gases, as already described. The steam-supplying arrangements are shown at S to S8. The steam and distillation products are drawn off by a Baker's or other exhauster, to the condensers, through a main, A5. The charge in the retort gradually passes downwards owing to the periodical removal of spent shale below, fresh shale being at the same time introduced through the hoppers, and the descent being so regulated, that no shale containing oil passes into the fireclay portion of the retort. The shale in this portion, however, still contains nitrogen, most of which it yields up to the steam in the form of ammonia, so that a large increase of the production of sulphate of ammonia results. Each retort holds about 30 cwts., and about twenty-four hours is occupied in the passage of the shale from the top to the bottom. A fresh charge of 8 cwts. is put in at the top, and a corresponding proportion of the spent shale removed below, every six hours. Each bench of eighty retorts distils from 100 to 120 tons of shale every twenty-four hours, with a consumption of from 1 to 3 cwts. of coal per ton of shale. The quantity of steam required varies with the character of the shale, and is equivalent to 80 to 120 gallons of water per ton.

A modification of the Young and Beilby retort, designed by Messrs. J. & H. Armour, is described in a paper by Mr. F. J. Rowan, "On the Physical Conditions existing in Shale-distilling Retorts."[1] This retort was in use at the works of the Hermand Oil Company, but the works have been pulled down.

The **new Henderson retort**[2] now in use by the Broxburn Oil Company, and by this company only, is also a modification of that of Young and Beilby, and, in common with the latter, is worked on the continuous system, while the old Henderson retort, already described, was worked on the intermittent principle. The following is a description of the new retort:—

"The object of this improved retort is to get a larger yield of sulphate of ammonia without deteriorating the quantity and quality of the crude oil. The retorts are vertical, 28 feet long. In the upper cast-iron portion of the retort, A (Plate XIV.), the oil is first distilled off the shale at a temperature of about 900°F. The spent shale is then passed downwards into the brick portion of the retort, B, which is kept at a constant temperature of about 1,300° F. The shale, in passing down through the retort, is kept in constant motion by a roller, C, at the bottom, which delivers it into a hopper, D, below, at the required rate. This continuous motion largely increases the yield of ammonia and permanent gases from the carbon of the shale; it also regulates the working of the quantity of shale to be put through, and prevents the exhausted material from fusing and sticking in the retort under the high temperature. Steam is passed into the spent shale, and is thus superheated before entering the retort. All the products of distillation are drawn off the top of the retorts through the branch pipe, E.

"The retorts are heated with gas made from dross coal in gas producers, and introduced at the ports, F. The incondensable gases are also returned to the heating chambers, and mixed with the producer gas, to assist in heating the retorts.

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[1] *Journ. Soc. Chem. Ind.*, x. (1891), 439.

[2] Patent, No. 6,726, 1889.

"On the tops of the retorts are fitted large malleable-iron hoppers, capable of holding about eighteen hours' supply of the raw shale. These have been found to be of great advantage in the regular working, in dispensing with night and Sunday labour in breaking shale and charging retorts."

Comparison of Past and Present Retorts, as worked at Broxburn.

"The old Henderson patent retort of 1873 gave, with the Broxburn shale, about 31 gallons crude oil, 16 to 17 lbs. of sulphate of ammonia, 75 per cent. spent shale containing 12 or 13 per cent. of combustible matter, which was dropped hot into the furnace below for fuel, and about 2,000 cubic feet of permanent gas. With the present retort, after extraction of the crude oil, 31 gallons to the ton, the spent shale passes into the brick retort below, to be acted on by steam at a high temperature. This gives, for fuel, about 15,000 cubic feet of gas, similar to producer gas, per ton of shale, and the sulphate of ammonia is increased to 44 lbs. per ton. With Drumshoreland shale at the Broxburn Oil Company's Roman Camp Works, the crude oil got is about 20 gallons per ton, and sulphate of ammonia about 72 lbs."

Both the new Henderson retort and the Hermand retort have been held to be infringements of the patent for the Young and Beilby retort, and royalty has been paid in respect to the first named.

The retort already referred to as being under trial at the works of the Pumpherston Oil Company, resembles the Young and Beilby retort in general principles, but is of much greater diameter (about 3 feet at the widest part, thus taking a charge of 5 or 6 tons, instead of about 30 cwts.), and is provided with a novel and effective arrangement at the base for controlling the discharge of the spent shale. It was patented by James Bryson, James Jones, and William Fraser.[1]

Condensation.—The vapours evolved from the shale amount to about 3,000 cubic feet per ton. They are passed through a series of 70 to 100 vertical 4-inch pipes, the lower ends of which are fitted into a chest, and about one-third is condensed. The condensed liquor, consisting of about 75 per cent. of ammoniacal liquor and 25 per cent. of oil, flows into a tank, and after spontaneous separation, the two products are pumped away separately for further treatment. Part of the uncondensed gas is in some cases purified and used for illuminating purposes. It is of about 25-candle power. The remainder is used as fuel, usually after further treatment by compression or scrubbing to remove the whole of the condensable vapours.

The scrubbing process consists in passing the gas through a series of coke towers in which it is exposed to streams of oil and water, the volatile hydrocarbons being removed by the oil, and the ammonia by the water. Usually there are three towers, the first of the series for oil and the two others for water. Intermediate oil of a specific gravity of 0·856 is commonly employed, and this so completely absorbs the light hydrocarbons that the illuminating power of the gas is reduced to about half a candle. The hydrocarbons are recovered from the oil by distillation, about 2 gallons of "gasoline" per ton of shale being thus obtained. The water scrubbing yields about 3 lbs. of sulphate of ammonia per ton.

In the **compression process** which was introduced by the late

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[1] English patent, No. 8,371, 1894.

Mr. J. Coleman, the gas is drawn from the condensers by two double-acting pumps, and, after being compressed to 100 or 120 lbs. per square inch, is forced through three tubular condensers, the first two of which are cooled by water, while the third is cooled to 40° or 50° below zero Fahrenheit by the expansion of the uncondensed gas. By this process, about 1¼ gallon of gasoline is obtained per 1,000 feet, at a cost of 2½d. per gallon. It is found to be much more expensive, and is therefore less used than "scrubbing."

From the **ammoniacal liquor**, the ammonia is driven off by the application of heat in stills, the evolved vapour being conducted into "cracker boxes," which are now usually of circular form, and about 5 feet in diameter and depth. In these boxes, the ammonia is brought into contact with sulphuric acid of about 50° Tw. in strength, and is thus converted into sulphate. Wilton's form of cracker box, which is now generally in use, is provided with an arrangement for the automatic discharge on to a drying table, of the sulphate of ammonia as it is deposited in the well of the box, and the process is worked continuously.

For the treatment of the ammoniacal liquor, the ordinary horizontal boiler stills formerly used have been superseded by "column" stills, in which the liquor is exposed, over a large area, as it passes from top to bottom of the still, to the action of a current of steam.

In **Henderson's still** (Fig. 144), patented in 1885, No. 15,836, the ammoniacal liquor is admitted at 8 into an annular, open-topped channel, 10*a*. It runs round this

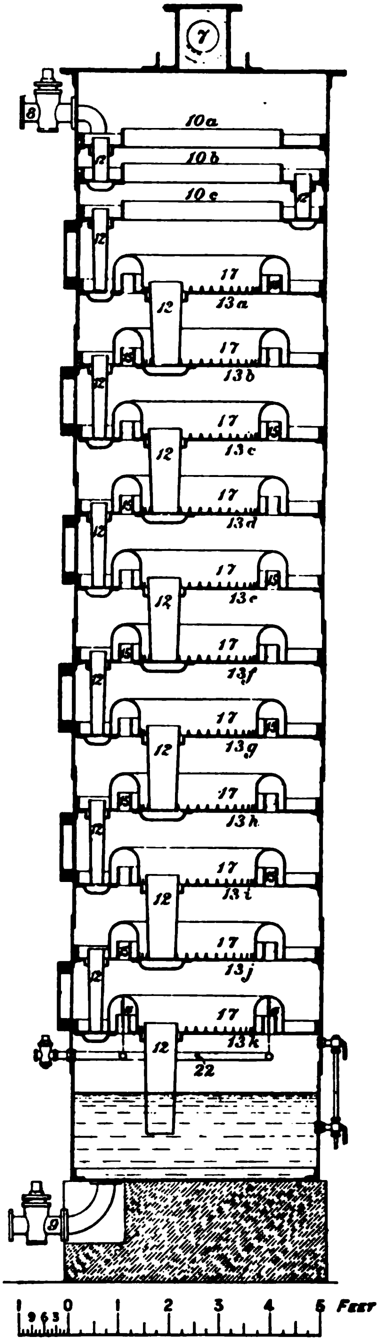

Fig. 144.

channel, descends through a pipe, 12, into a similar channel, 10*b*, travels over horizontal diaphragms, 12*a* to 13*k*, and in this manner descends from the top to the bottom of the still. Each of these diaphragms consists of an outer annulus and an inner removable disc, between which is thus formed an annular opening, 15, and upon this is placed an annular cap, 17, dipping into the annulus and the inner disc. The sides of the cap, 17, are notched below to within half an inch of the working level of the ammoniacal liquor. The outer and inner parts of each diaphragm communicate at one place, where the continuity of the opening, 15, is broken.

Steam admitted by a perforated pipe, 22, impinges upon the lower cap, 17, and passes upwards at every notch in the cap, through the liquid and through the openings, 15, and finally escapes at 7, with the ammonia vapour, to the "cracker boxes." The tubes, 12, are arranged alternately on the outer and inner parts of the diaphragms, 13*a* to 13*k*, so that the liquor is compelled to traverse a large area before it is drawn away exhausted at 9.

It is stated that, owing to the perfect circulation of the liquid and to the innumerable points at which the steam passes through and agitates it, no less than 45,000 to 50,000 gallons of ammoniacal liquor can be treated in a single still, per day, against about 3,000 to 4,000 gallons in the old form of still. Three steam boilers also do the work which formerly needed six.

The importance of the ammonium sulphate to the manufacturers of shale oil is shown by the fact that in 1891 no less than 26,600 tons of ammonium sulphate was obtained from shale in the United Kingdom, the amounts for 1890 and 1889 being 24,730 and 23,953 tons respectively.[1]

Crude shale oil is of dark green colour, has a specific gravity of 0·860 to 0·890, and, as at present manufactured, with the newer forms of retorts, has a setting point of about 90° F. It contains from 70 to 80 per cent. of members of the paraffin and olefine series, together with alkaloidal bases of the pyridine series and some cresols and phenols. Beilby[2] states that average Scotch shale oil contains from 1·16 to 1·45 per cent. of nitrogen, mainly removable by sulphuric acid of specific gravity 1·220, and mostly remaining in the pitchy residues left on distillation. The lightest distillate, known as naphtha, contains from 60 to 70 per cent. of olefines and other hydrocarbons acted upon by fuming nitric acid, and the lubricating oils consist mainly of olefines. The **paraffin wax** mainly distils over with the oil of specific gravity above 0·840.

In the **refining of crude shale oil**, the greatest care is exercised to prevent dissociation of the paraffin, large volumes of superheated steam being passed into the still, through a perforated pipe, at a pressure of from 10 to 40 lbs., to facilitate distillation at the lowest possible temperature. Under the old system of intermittent distillation, which is now only practised at the works of Young's Company, stills with cast-iron bottoms and malleable-iron upper parts are employed. The stills formerly had a capacity of from 1,200 to 1,400 gallons, but those now made usually hold from 2,000 to 2,500 gallons. Figs. 145 and 146 represent a still of 1,300 gallons capacity and its condenser. Each still has a separate water condenser, the flow of water being so regulated as to maintain a temperature suited to the nature of the distillate. The usual condensing surface is 230 feet of 4-inch pipe. Before the distillate passes to the receiver, it is run into an oblong separator-box with a water outlet at the bottom and an oil outlet higher up. In this, the water resulting from the condensation of the steam, separates from the oil, and the two are run off to their respective tanks. The still is first heated from below for about ten or twelve hours, or until the whole of the water has been expelled, after which, steam is introduced in gradually increasing quantity until, when the heavier oils are coming off, the distillate is accompanied by 15 to 25 per cent. of water. The oil is distilled to dryness, the time occupied in running a 2,500 gallon charge being altogether from twenty to twenty-four hours, and the steam is not shut off until three or four hours after the distillation ceases. The still is then allowed to cool for twenty-four hours, and the coke is removed from it. The coke is worth from fifteen to twenty shillings per ton, and represents, in the case of the best crude oils, about 4 or 5 per cent. of the oil, but in the case of less pure oil or where distillation has not been well conducted, may amount to 8 or 10 per cent. To prevent explosion arising from the choking of the condenser pipes, the still is provided with a safety valve in communication with a pipe through which the distillate escapes. The naphtha (specific gravity 0·740), which is volatilised during the first stage of the distillation, is collected separately, but the remainder of the distillate is usually run into one tank and is known as "once-run" oil.

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[1] *28th Annual Report on Alkali, &c., Works by the Chief Inspector*, 1892.

[2] *Journ. Soc. Chem. Ind.*, 1891, p. 120.

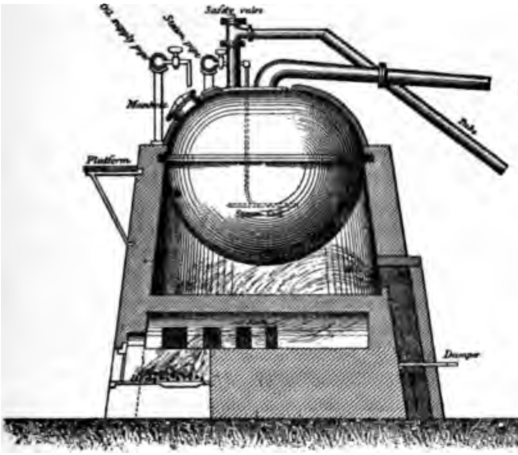

Fig. 145.

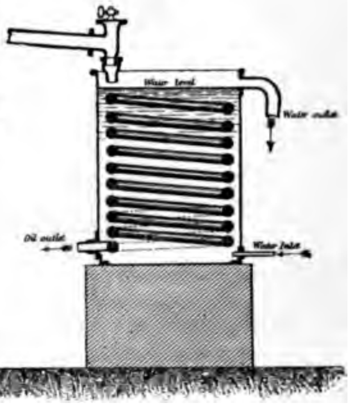

Fig. 146.

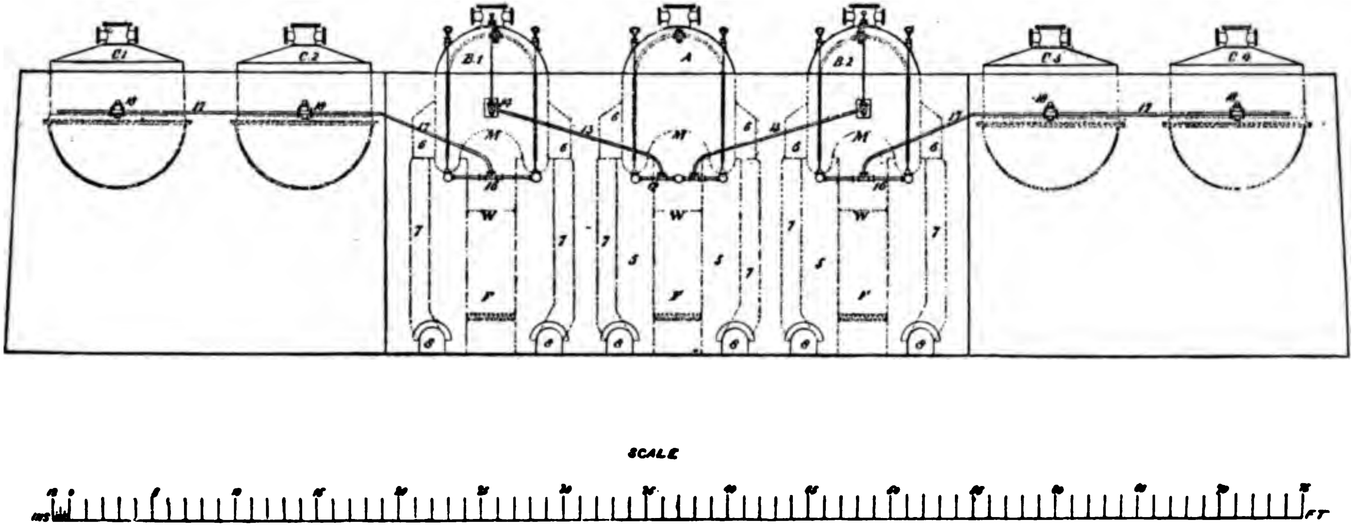

Fig. 147.

In Henderson's system of continuous distillation, patented in 1885,[1] which is now generally employed, there is a primary wagon still, A (Figs. 147 to 149), connected with two side stills, B1, B2, which are further connected with pot-shaped coking stills, C1, C2, C3, C4. The oil having been heated in feed-heaters, 21, by the gases evolved from the hottest still, is passed into the still, A, where the temperature is so regulated as to drive off only naphtha of about 0·760 specific gravity.

The oil is continuously drawn off from the back of the still, A, into the backs of the stills, B1, B2, where the temperature is sufficiently high to distil off a light oil of specific gravity 0·820 to 0·830. From the front of each of the stills, B1, B2, the oil runs into one of the connected pair of coking stills. The coking stills, in which the distillation is carried to dryness, are used alternately, so as to admit of the removal of the coke. The oil enters the still, A, by a pipe, 9, which just dips below the surface of the oil, while it is supplied to the stills, B1, B2, by horizontal pipes, 10, fixed a short distance above the bottom, and delivering the oil at the end of the still opposite to that at which they enter.

The lateral parts, D, of the stills are built into walls, 5, to protect them from the fire heat. The fire-grate, F, is placed low, so as to form a combustion chamber, and in communication with this there are flues, 6, 7, 8.

The still, A, has outlet valves, 11, to the external piping, 12, which has branches, 13, with valves, 14, to the feed pipes, 10. The stills, B1, B2, have similar pipes and valves, 15 to 18, through which they discharge into the coking stills. Rods, 19, are connected with safety stop plugs inside the stills, and internal valves, 20, are connected with the feed inlets. Branch pipes, 32, connected with a main, and having perforated branches, 33, are provided for injecting steam into the stills.

The preliminary heater for the oil consists of an outer cylinder, 21, a pipe, 22, conveying vapour from the still, B1 or B2, a pipe, 23, conducting the vapour to a condenser, and an inner cylinder, 24, into and from which the oil to be heated travels by pipes, 26, 27, the latter passing at 30 down the cylinder, 24. Stop cocks, 28, 29, and a valve, 31, for discharging condensed liquid and gas, are also provided.

As the more volatile constituents distil off, the residue sinks to the deep sides of the still bottom and passes thence to the next still as described. Thus, the distillation requires no attention beyond regulation of the heat and changing the course of the current from the stills, B1, B2, to the coking still. It is stated that with one such set of stills as much work can be done as was formerly accomplished by the use of thirty-two separate stills.

Sometimes there is a separate primary still, A, for each of the stills, B1, B2, and another still between these and the coking stills. This is particularly desirable when a large quantity of oil is treated; in the third stills the distillation is conducted nearly to dryness before the residues pass to the coking stills. The distillate from these third stills

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[1] No. 13,014.

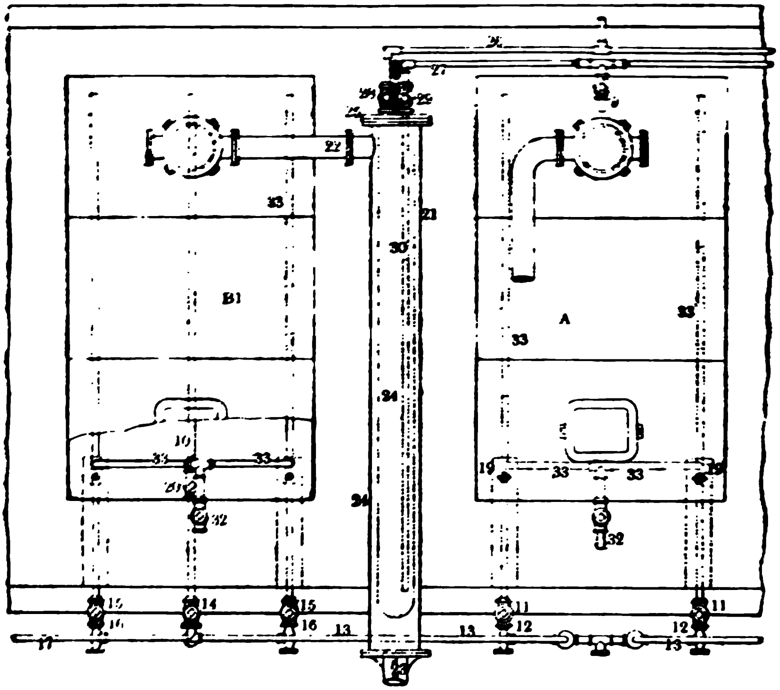

Fig. 148.

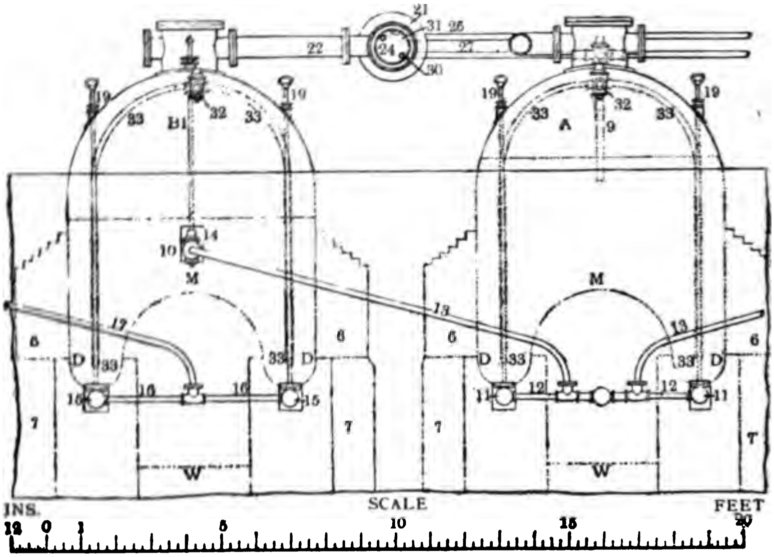

Fig. 149.

has a specific gravity of 0·870 to 0·880 and contains most of the paraffin. On the other hand, where only small quantities of oil are treated, the stills, B1, B2, may be dispensed with, the still, A, being connected directly with the coking stills.

In a **continuous distillation** process devised by Messrs. Young and Beilby[1] the still is of horizontal cylindrical form, and is partitioned transversely, a series of separate chambers being thus formed through which the oil successively passes. Each chamber is provided with a pipe leading to a condenser, and the furnace is so arranged that the heat is graduated, one end of the still being much hotter than the other. The oil enters the first chamber at the cool end of the still, and the residue is discharged from the last chamber at the hot end. This system has not hitherto been put into practical use.

The **"once run"** oil usually passes through three distinct stages of chemical treatment and distillation before it is marketable.

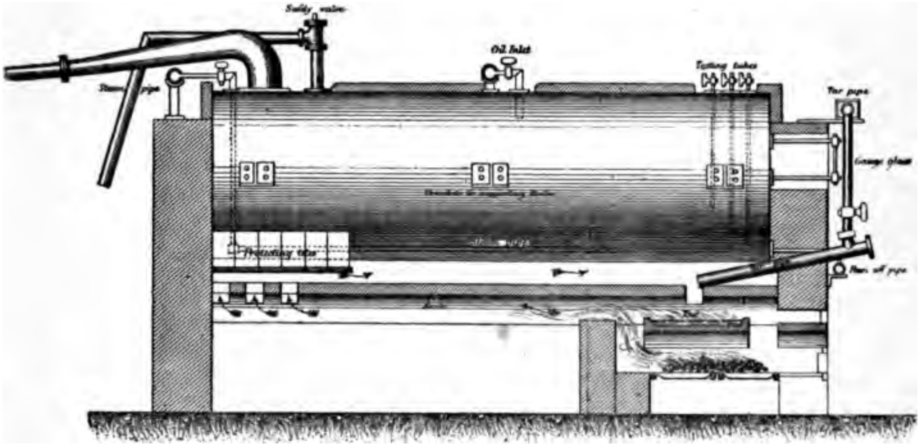

Fig. 150.

The agitators in which it is treated with acid and alkali, are of various forms, and vary in capacity from 2,000 to 20,000 gallons. They are set on different levels, so that, after the acid treatment, the oil may be run into a lower agitator for treatment with alkali. One form consists of a horizontal cylinder 6 to 8 feet in diameter, fitted with a shaft carrying paddles which revolve between fixed discs. Another form consists of a vertical cylindrical tank, 8 to 16 feet in diameter, with egg-shaped bottom, in which the agitation is effected by means of compressed air.

The oil is treated at the lowest temperature which will prevent separation of solid paraffin—*i.e.*, at about 100° F.—a temperature maintained by steam coils. The sulphuric acid used, may either be fresh acid of specific gravity 1·720, or may be the acid tar obtained as hereafter described in the treatment of another distillate. The acid is usually added in two or three portions, and admixture is effected by means of the air blast, the acid tar being separated after each addition.

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[1] Patent No. 6,094, 1884.

After settling for at least four or five hours, the oil is run off by gravitation into the alkali agitator, where it is treated with soda lye of 1·3 specific gravity (60° Tw.). The alkali may, like the acid, be advantageously added in successive quantities, the treatment commencing, in some cases, with the use of a little alkali of as low a specific gravity as 10° Tw.

During the acid and alkali treatment, from 26 to 30 per cent., calculated on the crude oil, is lost.

The oil is next fractionated, either by the intermittent or the continuous system. Fig. 150 represents a still for the former system. It is heated below as shown, partly by coal and partly by tar produced in the refining operations.

After the most volatile fractions have distilled off, steam is blown in through a pipe at the bottom of the still. In many cases, the distillate, with a density up to 0·770, constitutes the crude naphtha, and that up to a density of 0·850, the burning oil. The remainder of the distillate, which solidifies at common temperatures, consists chiefly of lubricating oils and paraffin. These three fractions are delivered from the condensers into separate tanks.

Although the crude-oil stills of Henderson may be applied for the continuous distillation of the once-run or other oils obtained in the process of refining, the inventor prefers another form of apparatus which he patented in 1883 (No. 540).

This arrangement (shown in Figs. 151 to 155) comprises a set of three horizontal cylindrical stills, each 7 feet in diameter and 19 feet in length, and each fitted with an outlet pipe in the bottom at one end. At the same end, but at a higher level, an inlet pipe passes into the other end of the still, so that the inlet and discharge are as far as possible apart. The vapours from each still rise into the usual dome or vapour chest, 24, and pass thence into a "feed-heater," 26, where they raise the temperatnre of the oil as it enters the still. The oil circulates from still to still, as in the Henderson continuous system already described, and two or more residue stills, one of which is shown at 41, are provided to receive the residues from the third still, one being used while the other is being cleaned out.

As coking takes place to some extent in the third still, this is fitted with plates or dishes, 42, with a view of promoting circulation of the oil, and preventing the adhesion of the coke to the bottom of the still, the carbonaceous deposit collecting on the plates, from which it is readily removed. These plates extend along the still, and the lower portion is formed with a curve, as shown, corresponding with that of the still. They are hinged to straps riveted to the sides of the still, and are supported by feet resting on the still bottom. Chains may be attached for turning up the plates for cleaning.[1] The oil circulates under the plates, up the sides of the still, and back towards the

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[1] The author is informed that these plates are no longer used.

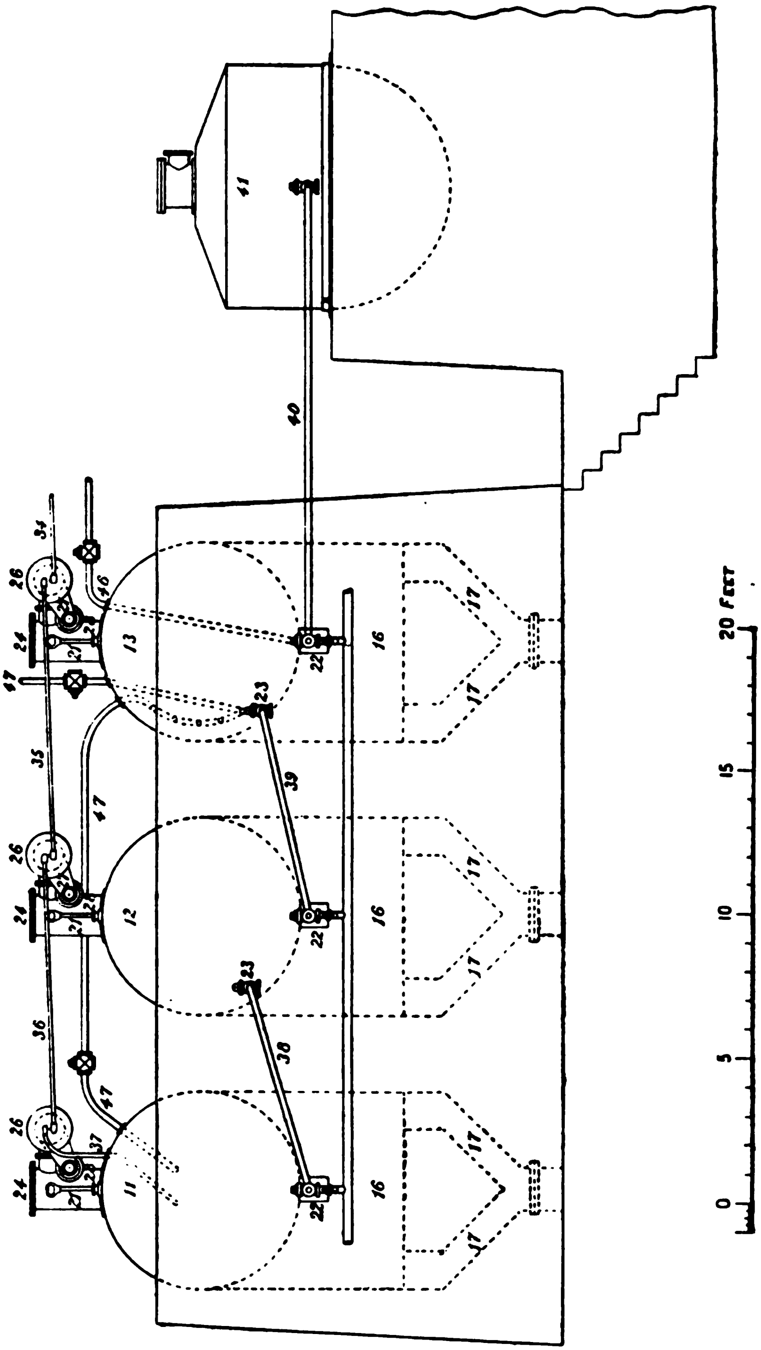

20 Feet

Fig. 151.

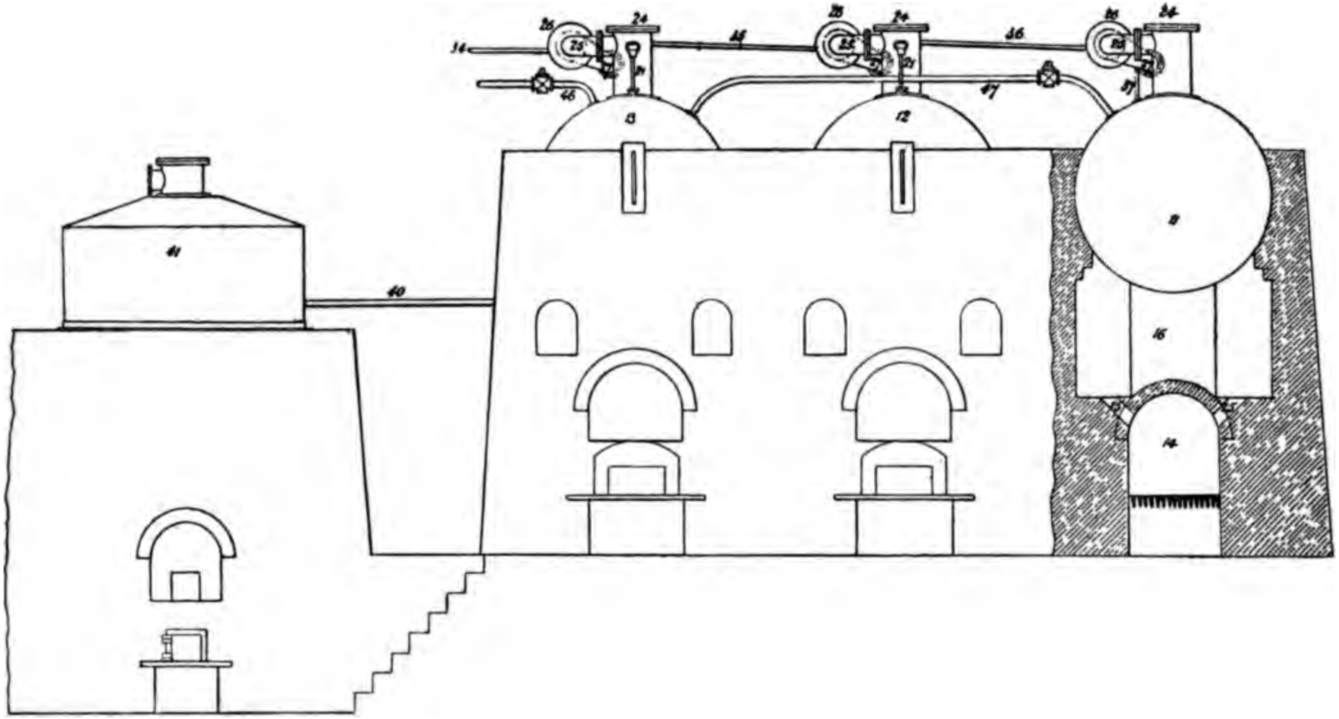


Fig. 152.

Fig. 153.

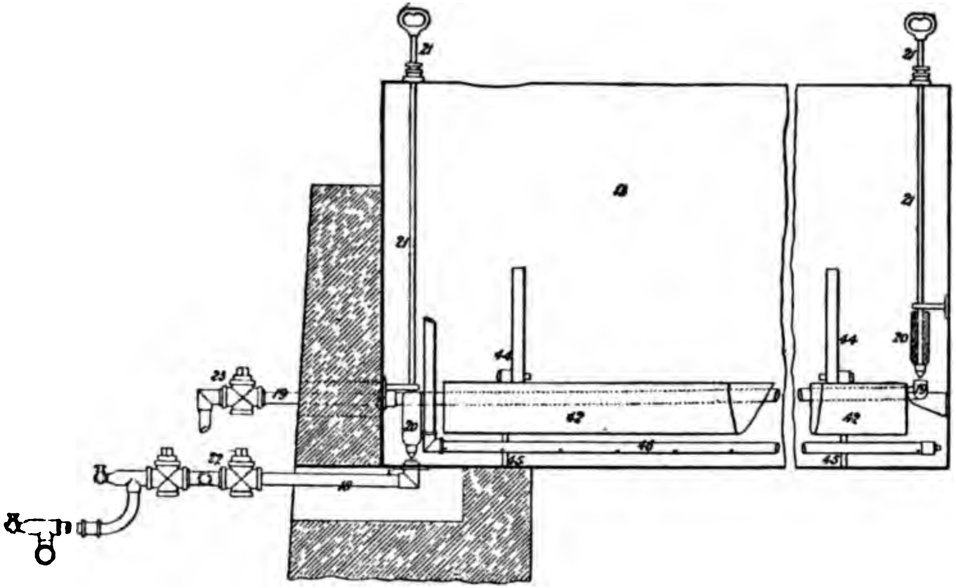
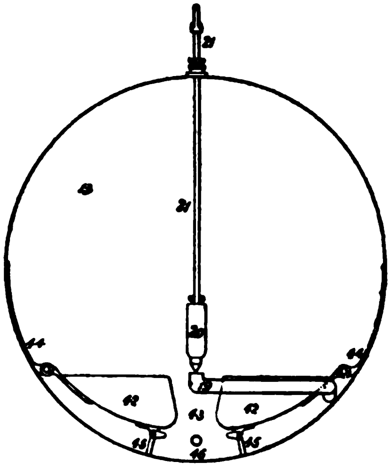


Fig. 154.



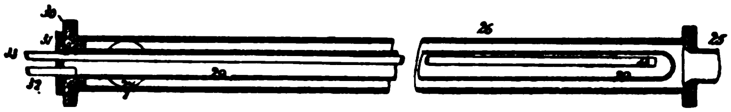


Fig. 155.

middle, the circulation being assisted by steam jets which issue from a perforated pipe, 46. It is claimed that a set of three stills, worked continuously for twelve days, will treat 285,000 gallons of oil, while under the old system only 126,000 gallons could be treated in this period in stills of the same capacity. There is also said to be a considerable saving in labour, fuel, and repairs.

The following is a detailed description of the various parts shown in the figures (151 to 155).

Fig. 151 is a back elevation of a set of three stills, with one of the residue stills. Fig. 152 is a front elevation, partly in section. Figs. 153 and 154 are enlarged longitudinal and transverse vertical sections of the third still, and Fig. 155 is an enlarged longitudinal section of one of the feed-heaters. The same numerals apply to the whole of the figures. 11, 12, and 13, stills; 14, furnaces; 15, lateral openings for fire gases; 16, heating chamber; 17, lateral flues; 18, discharge pipes from stills; 19, inlet pipe to stills 12 and 13; 20, safety-plug valves to inlet and outlet pipes; 21, rods connected with the valves and passing through stuffing boxes; 22, 23, external stop-cocks; 24, domes of stills; 25, curved branches from domes; 26, horizontal vapour pipes, forming feed heaters; 27, outlets for vapour; 28, vapour pipes to condensers; 29, inner cylinders of feed heaters with flanges, 30, and closing plates, 31; 32, inlet pipes for feed oil; 33, outlet pipes for feed oil; 34, 35, and 36, pipes conveying heated oil to stills; 37, delivery pipe into still 11; 38, delivery pipe from still 11 to still 12; 39, delivery pipe from still 12 to still 13; 40, delivery pipe from still 13 to residue still 41; 42, dishes or plates (usually applied to the third still) for promoting circulation and for collecting coke; 43, space between the dishes; 44, straps or hinges of dishes; 45, feet of dishes; 46, perforated steam pipe; 47, pipe, which may be used as a feed-heater.

The burning oil is next twice treated with 0·5 to 0·75 per cent. of sulphuric acid of 168° Tw., and allowed to settle for twelve to eighteen hours, the acid which separates being utilised in treating a charge of "once run" oil. It is then agitated with 0·5 per cent. of caustic soda solution of 7° Tw., and after that with 1 per cent. of a solution of 62° Tw. It is then again fractionally distilled, naphtha being collected up to 0·760 specific gravity, burning oil up to 0·840 to 0·850, the distillate with a still higher density, being a heavy oil which yields about 10 per cent. of soft paraffin scale. The residues from the distillation are redistilled, and yield from 5 to 10 per cent. of burning oil, and a heavy oil from which soft paraffin is obtained.

The final chemical purification of the burning oil resembles that last described, but only half the quantity of acid is employed. The character of the fractionation to which the oil is subjected, depends upon the practice prevailing at the refinery, and upon the requirements of the market. In some cases the first distillate, up to 0·790, is collected for "special" burning oil; that from 0·790 to 0·806 for No. 1 burning oil; and that from 0·806 to 0·820 for No. 2 oil. The fraction up to 0·825 is mixed with No. 1 oil, and that from 0·825 to 0·840 with the special oil. From 0·840 upwards, the distillate contains a small proportion of paraffin, and is used for producing "marine" oil.

Crude shale **naphtha** includes the crude "gasoline," of specific gravity 0·700 to 0·770, obtained from the shale distillation, and the light fractions from the first and second distillations of the crude oil. It is refined by agitation with 0·1 to 0·2 per cent. of sulphuric acid for fifteen minutes, followed by a similar treatment with 0·5 per cent. of acid. After settling for twelve hours, the tar is drawn off and the naphtha is run into another vessel, where it is agitated with 1 per cent. of caustic soda solution of 10° Tw., after which it is allowed to settle for twelve hours and is then distilled. The first distillate from crude gasoline (up to 0·695 specific gravity) is redistilled, the remainder (about 0·718 to 0·720 specific gravity) being classed as naphtha. The light portion yields finished gasoline of 0·640 to 0·660 specific gravity. Formerly the light distillates from the first and second distillations of crude oil were so fractionated as to yield naphtha of 0·720 to 0·730 specific gravity, for sale; naphtha of specific gravity 0·750, for use in the refinery in dissolving paraffin scale; and naphtha of 0·800 specific gravity, which was mixed with the burning oils before the third rectification.

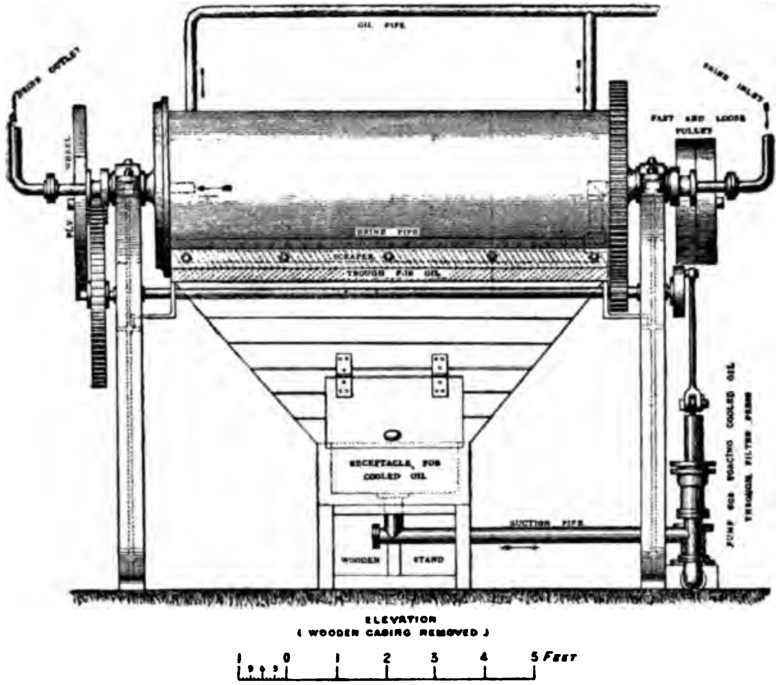
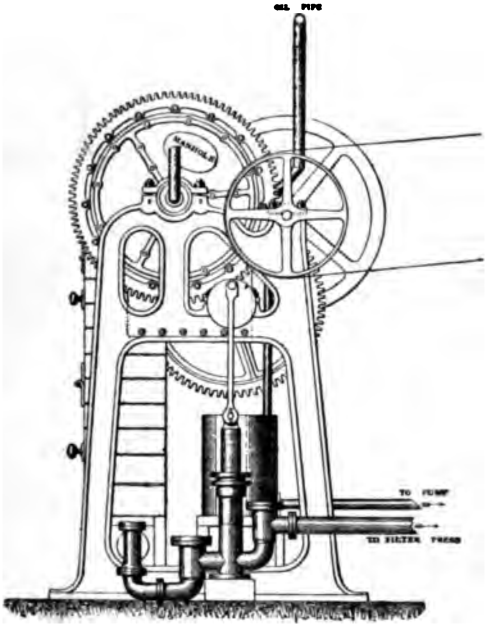


Fig. 156.

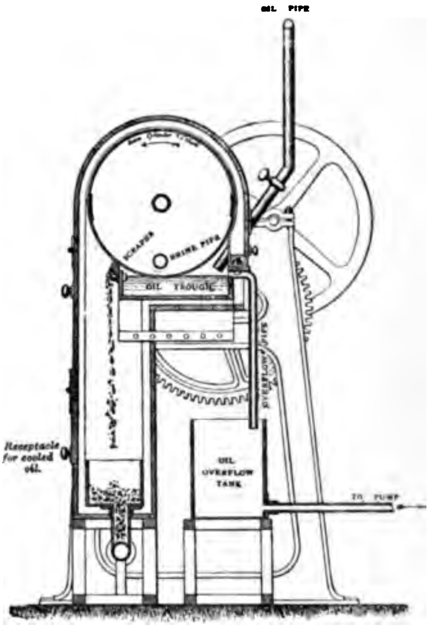
At one time **paraffin scale** was produced from the heavy oils obtained in the first, second, and third distillations. The oil resulting from the first distillation yielded **hard scale**, while the other two, as also the oil expressed from the hard scale, yielded **soft scale**.

The heavy oil from the first distillation was usually crystallised in shallow tanks, in which it was left for two to four days, according to the season, and the semi-solid mass was placed in filter bags in which it was subjected to a pressure of 25 lbs. per square inch, in perforated cylinders 5 feet 6 inches in diameter, and 3 feet high. The separated paraffin was again compressed between iron plates at a pressure of two or three hundred lbs. per inch, and being thus further freed from oil, was set aside for refining. It had a melting point of about 125° F.



END ELEVATION.

Fig. 157.



CROSS SECTION SHEWING WOODEN CASING.

Fig. 158.

The **soft scale** was obtained from the expressed oil, and from the other heavy oils containing it, by refrigeration, followed by treatment in a filter press. The method of **cooling** adopted consisted in placing the oil in trays, into which dipped slowly revolving drums (Figs. 156 to 158), kept at a low temperature by the passage through them of cooled brine, or preferably calcium chloride solution, as having less action on the metal of which the drums were made. The oil which adhered to the drum in a semi-solid condition, was scraped off in the manner shown, and fell into a receptacle below. As this arrangement did not cool the oil effectively, it was in some cases replaced by a fixed cylinder (Fig. 159), jacketed so as to form a chamber through which the calcium chloride solution circulated. The cooled oil adhered to the inside of the cylinder, was removed by revolving scrapers, and carried into the body of the liquid, which thus finally attained throughout the temperature of the cooling medium.

For cooling the brine, the ether machines of Siddeley & Co. have been largely used. The ether is evaporated in a vacuum of 25 inches, and is recondensed at a pressure of 5 to 7 lbs. per square inch. The temperature of the brine or calcium chloride solution was reduced to about 10° or 15° F. With the modern refrigerating plant, the ammonia refrigerators of Pontifex & Wood are usually employed.

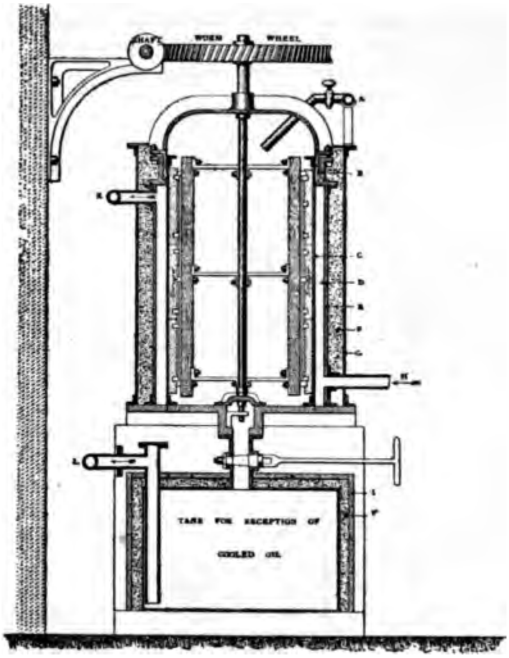

SHAFT
WORM WHEEL
A
B
K
C
D
E
F
G
H
L
I
F
TANK FOR RECEPTION OF COOLED OIL
UPRIGHT CYLINDRICAL REFRIGERATOR

Fig. 159.

A, oil inlet; B, packing; C, cylinder, $\frac{3}{16}$" thick; D, space for brine; E, cylinder, $\frac{3}{8}$" thick; F, non-conducting packing; G, iron casing; H, brine inlet; I, wooden casing; K, brine outlet; L, outlet to filter-press.

Improved appliances were introduced by Kirk, Southby, Beilby, Henderson, and others, with the object of rapidly cooling large quantities of oil, but it was found that their use resulted in the production of small crystals of paraffin from which the separation of the oil, especially in the case of the most viscous oils, was difficult and imperfect. The most modern improvements aim at the production of the largest crystals by slow cooling of the oil in bulk, and the inventions of Beilby and of Henderson will be described, as typical of these improvements and as being in actual use.

Beilby's process[1] was devised for the treatment of some very viscous oils at the Oakbank works, and is not in use at any other of the Scottish shale oil works. The apparatus comprises a series of rectangular cells, each 16 feet long, 8 feet deep, and about 1 foot wide, the width at the bottom being somewhat greater than at the top. The cells are arranged in sets of about ten, with intermediate cells through which cold brine or cold air circulates, and the apparatus is placed in a cooling-house in which the temperature is maintained at about the freezing point of water. The exposed ends of the brine cells have a surface of about 1,600 square feet, and it is this which cools the air in the house.

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[1] See *Journ. Soc. Chem. Ind.*, 1885, pp. 321 and 653; also Patent Specification No. 11,987, 1884.

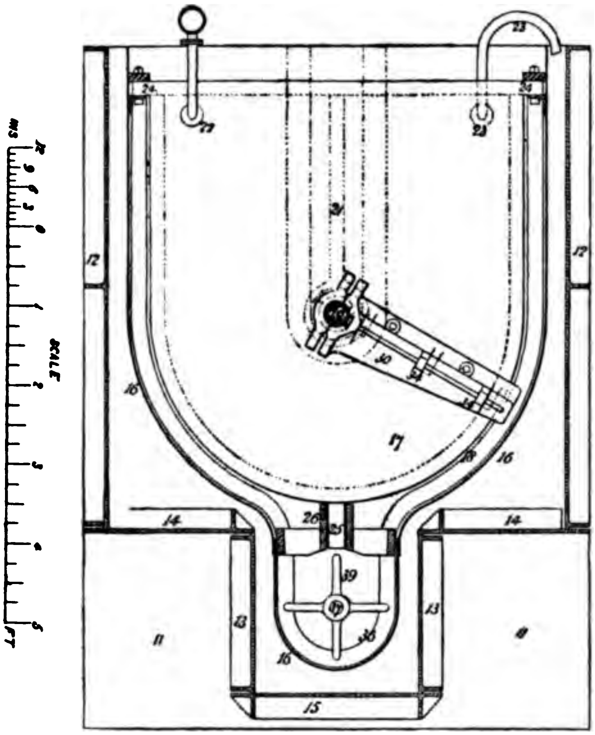

Fig. 160.

The oil has to remain in the cells for three days before it is sufficiently cooled, the cooling medium being brine at 10° F., and the temperature of the oil being reduced from about 100° F. to 15° F. When cold air is employed, a longer time is occupied in the cooling. The oil is thus frozen to a solid block which, owing to the tapered form of the cells, rests upon an archimedean screw, 1 foot in diameter, passing from end to end of the cell. The screws are worked by worm gearing, so that the frozen oil is sheared away as it gradually descends by its own weight upon the screw, and is discharged through a sluice valve at the end farthest from the gearing. The ground-up mass is passed through horizontal filter presses arranged beneath the cells, and the solid paraffin is thus separated from the oil. A pressure of 2½ tons per square inch is employed.

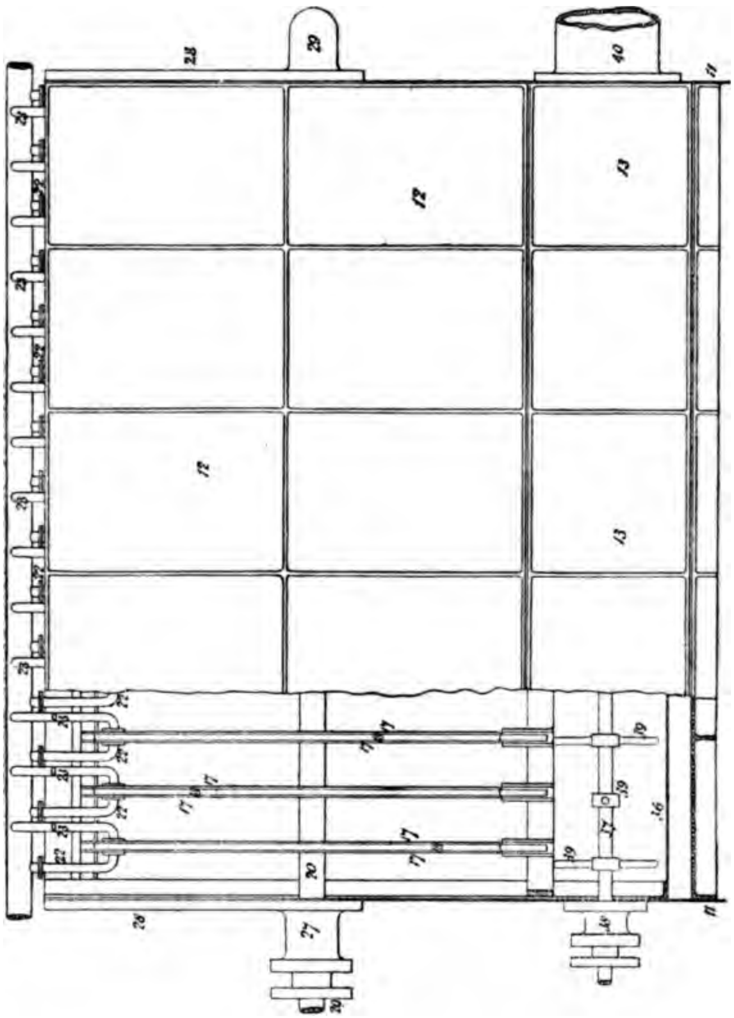

Fig. 161.

It has been found that when the screw makes 36 revolutions per hour, it discharges about 60 to 80 gallons of the mashed paraffin in the hour, and in one test experiment, it was found that when the frozen oil was at 32° F., a pressure of 3 tons on the pitch-line of a 12-inch worm wheel was required to start the screw moving in the midst of the mass.

The crystallisation of the paraffin is so perfect that the separation of the oil is comparatively easy, and the filter presses are now filled every three hours instead of every eighteen or twenty-four hours as in the old drum-cooling process. An important feature in this process is that the oil is expelled from the filter presses at almost the same temperature as the mashed paraffin enters them, the difference in temperature being only about 1° F., while in the old drum system this difference often amounted to 26° F. Thus a harder scale is produced and less paraffin is carried away in the expressed oil.

At the Oakbank works, an increase of about 25 per cent. in the yield of paraffin resulted from the introduction of this apparatus. This is partly due to the low temperature obtained, and partly to modifications in the refining processes made possible by the better crystallisation. The scale has an average melting point of 112° F., and on being refined, yields 74 per cent. of wax melting at 120° F., 11 per cent. of scale melting at 90° F., and 15 per cent. of oil and unrecovered soft scale.

Henderson's cooler (Figs. 160 to 162), patented in 1884, No. 9,557, consists of a jacketed trough having a curved bottom and divided into a series of transverse casings by metal discs, 17, each consisting of two thin plates bolted together, but with a space between, in which, as also in the jacket surrounding the trough, cold brine is circulated. The paraffin crystallises on the cold surfaces, from which it is constantly removed by scrapers, 30, so that successive portions of the oil are cooled. The sold paraffin accumulates in a well or channel, 36, where it is stirred up by rotary arms, so that it may be readily drawn away by a pump to the filter press. The following is a description of the principal parts of the apparatus :—

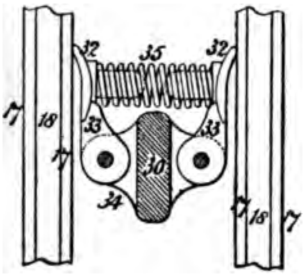

Fig. 162.

11, Vertical wrought-iron end plates of outer shell of trough.
12, 13, Flanged cast-iron side plates of same.
14, 15, Bottom plates of same.
16, Inner shell of sheet iron.
17, Discs of thin metal, riveted on a frame 18, forming transverse vertical casings.
20, Shaft carrying scraper-arms.
21, Bar to divide the upper part of space between discs, and thus cause proper circulation of cooling fluid.
22, Inlet pipes for cooling fluid.
23, Outlet pipes for cooling fluid.
24, 25, Projections to hold 17 and 18 in position.
26, Cast-iron frames, in which sockets are formed to receive 25.
27, Stuffing box for shaft.
28, Plates covering slots.
29, Bearing piece.
30, Scraper arms.
31, Cap to fix scraper arm to shaft.

32, Scrapers.
33, 34, Scraper lugs.
35, Helical springs to press the outer scraping edges against the discs, 17.
36, Channel into which the congealed paraffin descends.
37, Lower shaft passing out through stuffing box, 38, and carrying blades on arms, 39.
40, Discharge pipe.

The crude paraffin may be refined either by repeated crystallisation from naphtha or by "sweating," and either treatment may be followed by decolorisation with animal charcoal.

In the **naphtha treatment**, which has now given place almost entirely to the "**sweating**" process, the oily matters are removed by dissolving the paraffin in naphtha and allowing it to crystallise out. This operation is conducted three times, the naphtha being added to the melted scale, and as much as 25 per cent. of naphtha being used in the third treatment. The paraffin is re-crystallised by passing the solution over a drum cooled with water, or placing it in shallow tanks. It is then subjected to a pressure of 2 to 3 cwts. per square inch between layers of canvas. The expressed liquid contains the naphtha, the heavy oil, and part of the softer scale. The liquid from the third treatment is used for the second treatment of a fresh batch, and that from the second for the first, after which it is distilled to recover the naphtha. The loss of naphtha is about 150 to 200 gallons per ton of paraffin refined. The paraffin is freed from the adherent naphtha by being melted in a closed iron vessel, where it is exposed to a current of steam, at 20 lbs. pressure, for forty-eight to sixty hours, the steam being passed for the first three hours through a condenser to recover the greater part of the naphtha.

The paraffin is finally decolorised by agitation for one and a-half hours with finely-powdered dry animal charcoal, in pans, with a horizontal mixer. As the charcoal varies considerably in quality, the amount used ranges from 1½ to 6 per cent. by weight. The charcoal is mainly separated by subsidence, and the paraffin drawn off into filters, whence, freed from the suspended charcoal, it runs into moulds, and is thus formed into cakes of suitable size for packing. An account of the processes adopted in the decolorising of paraffin, has been given in the section dealing with the refining of petroleum.

In the sweating process, naphtha is not employed, the paraffin being simply exposed to such a temperature that the softer paraffin is melted and runs away, together with the oil. In carrying out the process, the crude scale is melted and heated to 170° to 180° F., in order that water and other impurities may be deposited, after which it is run into pans of 1 to 2 gallons capacity, and is allowed to solidify. The cakes of paraffin are then placed on cocoa fibre mats on slightly inclined shelves in ovens which are heated by steam pipes to about 30° F. below the melting point which the finished product is required to have. The fused portion, which runs out, is again treated in the same way and sweated at a lower temperature, and the drainings from it are cooled and pressed to obtain oil and scale, the latter being either worked up with the crude scale or mixed with a portion of the intermediate wax to increase its melting point, or worked up alone. The wax is finally treated with animal charcoal as already described.

In 1886, Messrs. R. Tervet and F. Alison patented a cooling and sweating arrangement for treating paraffin in large quantities.[1] It comprises a cooling and a sweating chamber, each formed in three sections, so that three qualities of wax may be treated. Each section of the cooling or outer chamber has on both sides of it twenty enamelled cast-iron pans, 20 to 30 feet in length, 30 inches in width, and 2 inches in depth. These pans contain sheets of canvas, and are filled with melted paraffin, which solidifies in them.

The sweating or inner chamber has twenty corrugated steel plate shelves, corresponding in length and position with the cooling pans, and slightly inclined towards gutters which receive the drainings. The sweating chamber is maintained at the required temperature by steam pipes. By means of a hand-winch at the end of each section, the canvas cloths are drawn, with the paraffin upon them, into the sweating chamber, where they are slowly passed over the corrugated plates. The cake cracks and parts freely with the oil and soft paraffin. By means of the winch, the cakes are finally drawn from the sweating chamber and delivered into a boiler, where they are melted. From this vessel the fluid paraffin is blown by steam into the "charcoalisers."

Mr. Tervet has patented another sweating apparatus,[2] in which, it is said, a first-class wax can be obtained from crude scale in one operation. The blocks of paraffin are first formed in coolers made slightly wider at the bottom, and are then allowed to descend into sweating cells which are arranged at such a distance below the coolers that the blocks enter them before wholly leaving the coolers.

The sweating cells are composed of wire netting or perforated metal, and are lined with coarse woollen cloth. As sweating proceeds, the separated oil runs into channels at the bottom of the cells. In order that the process may be carried out continuously, two or more sweating cells are arranged, one beneath the other, and arrangements for regulating the temperature around each are provided. The paraffin blocks pass from cell to cell, losing the greater part of their impurities in the first, the soft and intermediate paraffins in the second, and a further portion of harder paraffin in the third, if that is employed. The blocks may be 3 feet broad by 6 feet long, and arrangements are provided for retaining them in the cells until it is desired to allow them to descend into those below.

It is stated that such a three-cell arrangement may be charged every four hours, and that commencing with a scale melting at 112° to 114° F., a wax is obtained melting at 126° F. In this process, the material is subjected to successive sweatings without melting and recrystallising after each, and in that respect it differs from the ordinary method of "sweating," but, as far as the author is aware, neither this nor the jointly patented method previously described has ever been successfully put into practical operation in a refinery.

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[1] No. 8,756, 1886.

[2] No. 4, 1887.

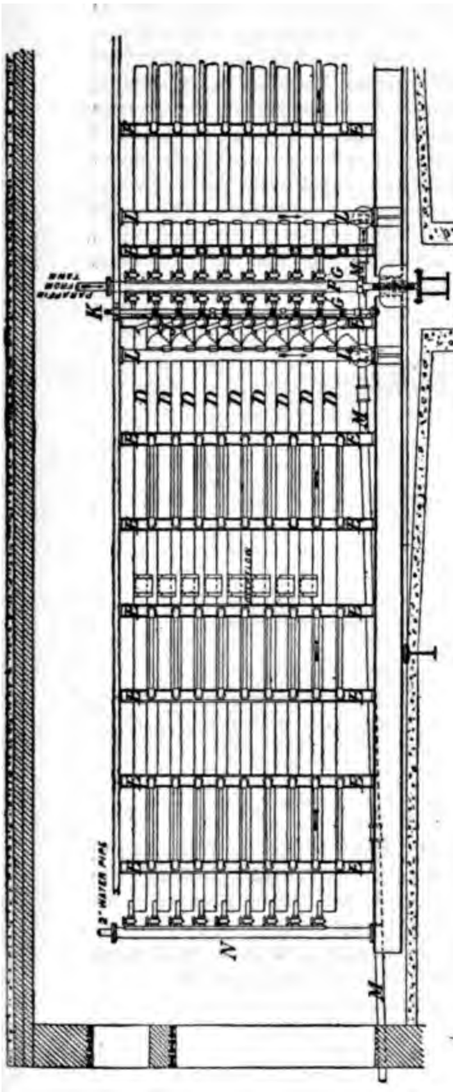

Fig. 163.

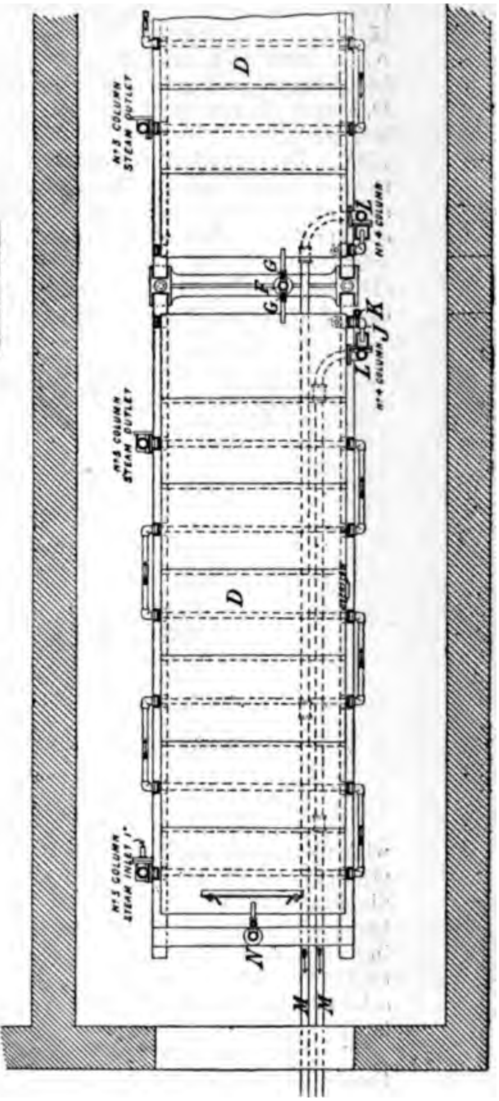

Fig. 164.

In the **sweating process** patented by Mr. Henderson,[1] and now very largely and successfully employed, a chamber, B (Figs. 163 to 165), about 52 feet by 13 feet by 10 feet high, having steam pipes, A, for heating it, and large doors and ventilators which may be opened for cooling it, is fitted with a number of superimposed horizontal trays, D, about 21 feet by 6 feet, and 6 inches deep, resting on transverse heating pipes, C, fitted in vertical standards, E. Each tray is provided with a horizontal diaphragm or strainer of wire gauze, of about 16 meshes to the inch. These diaphragms are fixed with bolts to the ends of the trays, and rest on cross bars. The bottoms of the trays communicate with short pipes with swivel nozzles, J, constructed to work with worm wheels on a vertical shaft, K, this arrangement allowing all the swivel nozzles from the bottoms of the trays to be turned at once. Before charging the trays, the diaphragms are covered with about half an inch of water from the small cocks on the charging pipes, N, which prevents the melted wax from running through the diaphragms. The crude, solid paraffin from the filter presses, after being melted in a tank, is pumped direct through the vertical charging pipes, and through the small cocks on to the surface of the water, to fill the trays, and when it has solidified, the water is run off, the cake of paraffin then resting on the gauze, and the doors and ventilators are closed.

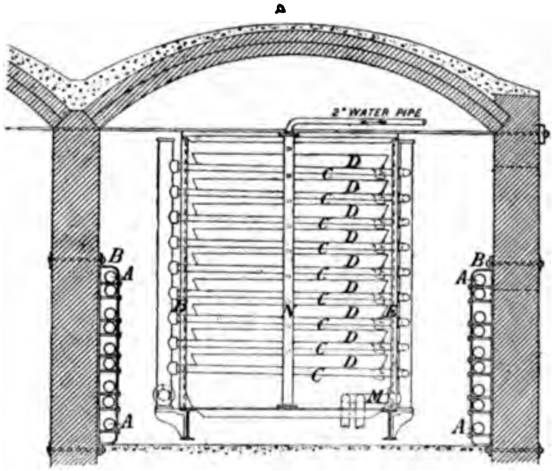

Fig. 165.

The stove is then heated for a considerable time to 80° F., and, finally, to the temperature at which the sweating is to take place, and the liquefied impurities are drained off until the outflowing paraffin sets on a thermometer bulb at 130° F. The various liquids separated in the refining of the wax, are drawn off through the swivelling nozzles into cups or hoppers on the standard pipes, L, which lead them into horizontal pipes, M, through which they pass to suitable receivers for collecting the various qualities of products. When the sweating is completed, the remaining wax is melted by increasing the temperature, and run off through the same outlets into a tank, whence it is pumped for treatment with charcoal as usual. Arrangements are provided at the ends of the horizontal pipes, M, for conducting the various products into their receptacles. The stoves are built of brick, and have double doors of iron and wood, with sawdust between. Each stove is fitted with two sets of nine pans each, and will take from two and a-half to three charges of 14 tons each per week, according to circumstances.

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[1] No. 1,291, 1887; and No. 11,799, 1891.

Mr. Sterry has patented a process for removing the oil from paraffin scale by kneading in a weak alkaline soap solution, at a temperature about 10° below the melting point. A similar process was patented in 1871 (No. 1,858) by Mr. J. Fordred.

The lubricating oils obtained are refined by the use of sulphuric acid and alkali, substantially in the same manner as the burning oils.

The following table shows the average yield of the various commercial products from crude shale oil at two of the principal Scottish refineries. The percentages are, however, often varied to suit market requirements:—

TABLE XLIX.—Young's Paraffin Light and Mineral Oil Company.

	Per cent.
Gasoline and naphtha,	6·09
Burning oils,	31·84
Intermediate and heavy oils,	23·97
Paraffin scale,	13·53
Total,	75·43
Loss,	24·57
	100·00

Broxburn Oil Company.

	Per cent.	Per cent.
Naphtha,		3·0
Burning oil,	30·0	
Gas oil,[1]	9·0	
		39·0
Lubricating oil,		18·0
Paraffin,[2]		10·0
Loss,		30·0
		100·0

The author is indebted to Mr. John Fyfe (Young's Company) and Mr. Kennedy (Broxburn Company) respectively, for these statements of the present (1895) yield.

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[1] This product, which may be classed with the burning oil, has become an important one, and a considerable quantity of it is now made.

[2] This represents refined or semi-refined paraffin, in ordinary merchantable condition. The loss in refining the paraffin is therefore included in the last item of loss in the processes.

Mr. R. T. Moore gives the following tables showing the products from 1 ton of shale, and their value, since 1877 :—

TABLE L.—PRODUCTS FROM 1 TON SHALE, AND TOTAL PRICE REALISED AT WORKS FOR THE REFINED PRODUCTS.

Year.	Crude Oil.	Naphtha.	Sulphate of Ammonia.	Total price per ton Shale.
	Gallons.	Gallons.	Lbs.	
1877, . . .	30·49	...	17 37	£1 3 2
1882, . . .	29·84	...	13·77	0 14 4
1887, . . .	27·96	...	28·95	0 11 2¼
1891, . . .	25·09	1·73	27·23	0 13 2

YIELD OF FINISHED PRODUCTS FROM 100 GALLONS CRUDE OIL.

Year.	Lighting and heating Oil.	Lubricating Oil.	Medium Oil.	Paraffin Scale.	Total.
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
1877, . . .	40·35	10·70	4·43	8·26	63·74
1882, . . .	31·64	14·35	11·08	10·41	67·48
1887, . . .	34·12	13·45	6·25	13·12	66·94
1891, . . .	30·81	12·63	11·7	14·72	69·87

NET PRICES REALISED AT WORKS FOR PRODUCTS.

Year.	Burning and heating Oil. Pence per gall.	Lubricating Oil. Pence per gall.	Medium Oil. Pence per gall.	Paraffin Scale. Pence per lb.	Sulphate of Ammonia per ton.
1877, . .	9·275	11·004	6·668	4·31	£17 5 6
1882, . .	4·313	7·347	4·005	2·40	18 2 5
1887, . .	3·160	2·200	1·060	2·125	10 5 0
1891, . .	4·176	3·715	2·806	2·262	10 7 1
1892, . .	3·400	3·005	2·250	1·750	10 0 0
1893, . .	2·730	2·950	2·100	1·750	11 12 6

The French Shale Oil Industry.—The following particulars of this industry, already referred to as regards the occurrence of the shale, are taken from the detailed description given by M. Chesneau[1]:— The shale is broken by hand or by machine-breakers into pieces about 4 inches cube, and is tipped into the top of the retort immediately after the previous charge has been exhausted. The retort is closed by a cast-iron lid luted with sand mixed with clay, and, as it is already strongly heated, distillation at once commences. The ammoniacal vapour which comes off during the first three or four hours is condensed in a worm, and the liquor flows into a receiver. The stream of vapour gradually becomes more and more charged with oil until, after twelve hours, oil alone comes off for about eight or ten hours. Finally, steam alone passes into the condenser, and this indicates the completion of the distillation. The uncondensed gases are sometimes used as fuel. Each retort distils a charge every twenty-four hours,

[1] *Ann. des Mines*, 1893, iii., 617-674.

and five men, at 2½ francs daily, are required for a bench of twelve retorts. There are sometimes twenty-four retorts in a bench. The distillation of the shale is not carried to exhaustion, so that the material retains a little bituminous matter, amounting, with the coke, to about 9 or 10 per cent. of carbon. It is discharged from the retort directly into the furnace, from which the exhausted fuel has just previously been discharged, and there acts as fuel for the next distillation. To facilitate the discharge of the contents of the retort and furnace, the bottom of both receptacles is made to open downwards like a door.

The retorts are of cast iron, and vary in capacity from 13 to 16 hectolitres (1 hectolitre equals 3·53 cubic feet), and the furnaces have a height of 1·5 metre, a width of 1·05 metre, and a depth of 1·1 metre. The arch of the furnace has seven openings—one in the middle, through which the shale falls from the retort, and six others for passage of the furnace gases to heat the sides of the retort. The bottom of the furnace consists of a double door through which the exhausted fuel is discharged into tipping trucks running on an under-ground tramway. There are two flues communicating with those on either side of the retort, and iron dampers are provided for regulating the draught. To avoid sudden change of temperature, the retorts are enclosed by fireclay blocks.

The crude oil is very dark in colour, and disagreeable in smell, and is purified by successive distillations, together with treatment with acid and alkali, followed by washing with water, the process resembling that which is adopted in Scotland, but superheated steam has not yet been utilised in the distillation either of the shale itself or of the crude oil.

The **Plamores refinery,** at Buxières, is capable of treating 12,000 hectolitres (264,000 gallons) yearly, while the St. Leger refinery, belonging to the Société Lyonnaise, is of five times that capacity, and has an actual output of about 53,000 hectolitres yearly.

The **St. Leger refinery** produces from the crude oil 36·48 per cent. of a burning oil of 0·815 specific gravity, 2·88 per cent. of "*huile lampante*" of 0·86 specific gravity, 1·49 per cent. of a lubricating oil of 0·886 specific gravity, 25 per cent. of green gas-oil of 0·895 specific gravity, and 20 per cent. of tar of 0·96 specific gravity, the loss being 14·15.

The **Autun** shales yield less oil than those of **Buxières.**. A cubic metre of shale yields 45 to 58 litres of crude oil (0·89 to 0·90 specific gravity), 50 to 60 litres of ammoniacal liquor, and 24 cubic metres of gas.

The cost of winning the shale is about 3·5 to 4 francs per ton, and the total cost of producing the crude oil amounts to 10 francs per hectolitre (about 4½d. per gallon). Experiments made by M. Roux, engineer of Mines and Works of Buxières and La Courolle, show that on the large scale, one cubic metre of shale, weighing 1·026 ton, yields 60 litres of crude oil of specific gravity 0·915 at 15° C. (58 litres per ton), while laboratory experiments on half a kilogramme of the shale gave results corresponding to 42 litres of raw oil of 0·973 specific gravity per ton, when conducted without the use of steam, and 84 litres of oil of 0·955 specific gravity per ton, when superheated steam was injected into the retort.

From these results and other considerations, M. Chesneau believes that a larger yield of both oil and ammonia might be obtained by causing the distillation of the shale to take place progressively, the greatest heat being applied at the bottom of the retort and the temperature gradually diminished towards the top, instead of the heat being almost uniformly distributed over the retort, as is the case at present.[1] He also suggests the use of superheated steam in the distillation of the shale and of the crude oil, and the introduction of processes resembling those in use in America for removal of sulphur from the crude oil.

The Brown-Coal Tar Industry.—The methods employed in the distillation of brown coal or lignite, which forms an important industry in the Prussian Province of Saxony, closely resemble those on which the shale-oil industry already described are founded. In 1880, there were twenty distilleries in Saxony, in which 1,536 retorts were employed, with a production in the year of 48,421 tons of tar from 9,458,603 tons of lignite.[2]

There are no hard and fast limits of demarcation in physical or chemical properties upon the basis of which a distinction can be drawn between lignite and ordinary coals. For instance, at Malowka, in Russia, a hard coal occurs, resembling, in appearance, a newly-formed lignite, and it was only after careful investigation that it was classified among the hard coals. According to Zinke, the only reliable method of distinction is the determination of age by the geological and palæontological conditions under which a coal occurs, the so-called distinguishing test with caustic potash, in which lignite gives a brown coloration, while hard coal exhibits no reaction, being misleading. English hard coals, and particularly the so-called dry coals, give the coloration, whereas the lignites of the northerly Alpine Tertiary formation lose this property as soon as they assume the character of anthracite.

According to Kremers, lignite should always yield, on destructive distillation, acetic acid, either free or in combination with ammonia, while hard coal yields free ammonia, but no acetic acid; this, however, is not an invariable rule as regards either variety.

By exposing anthracite, lignite, and hard coal to concentrated reagents for several years, Percy obtained distinguishing results—caustic potash, for example, attacking the first-named but slightly, colouring the solution pale yellow, and leaving a black residue; while it acted more strongly on hard coal, the solution being a pale yellowish-green; and still more vigorously upon lignite, the solution in this case becoming thick and of a deep red colour.

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[1] Since Chesneau's report was written, two of the French Shale Oil Companies—the Société Lyonnaise des Schistes Bitumineux, and A. Duchet (Buxières-les-Mines)—have adopted the Young and Beilby retort.

[2] Current information on the subject may be gained from the *Zeits. f. die Paraffin Mineral-öl u. Braunkohlen-Industrie* (Halle); and a description of the occurrence and treatment of the brown coal will be found in Schädler's *Technologie der Fette und Oele*, from which several of the tables, and much of the other information given in the following account, have been derived.

Another characteristic difference, according to Richters, is that on drying at 150° C., hard coal gradually loses weight up to a certain point, beyond which it again becomes heavier by oxidation, while lignite does not exhibit this latter property.

The researches of Schinnerer and Morawsky demonstrate that, by the action of fused alkalies on lignite, pyrocatechin is always formed, probably from proto-catechuic acid, produced by the dissociation of phlobaphene through the reaction of the alkali.

Brown coal frequently exhibits a woody structure, and contains remains of leaves, stems, &c., indicating its production from vegetable matter, but also occurs in amorphous, dense, slaty, or granular masses, in which all trace of structure is lost. The fracture varies, being, at times, even, irregular, smooth, dense, conchoidal, splintery, and fibrous, with wood-like texture. The ordinary brown coal exhibits no cleavage, while lignite cleaves in the direction of the wood fibres; and shale coal, "dysodil," and "blattkohle," cleave in the direction of the laminæ of the bed. The common brown coal, bituminous coal, and anthracite are generally more or less regularly stratified.

Thoroughly dried brown coal absorbs oxygen to the extent of about twice its volume, some descriptions taking up 11 per cent. in eight days, while the coke from this coal will absorb five times its own volume of oxygen. Under the weathering influences of the atmosphere, the earthy and lignite varieties of brown coal lose a variable proportion of their bituminous properties, and fall to pieces or powder. Thus the upper layers, when exposed, often differ from those below.

The burning properties may be tested by heating in a porcelain crucible, with admission of air; the lignites usually burning easily, with a weak, smoky flame, and emitting an unpleasant resinous or tallow odour.

The various brown coals are not classified according to their heating properties, like hard coals, but are placed in general groups, not being sufficiently distinct in their qualities to permit of a more scientific classification. Schädler recognises twelve classes:—

The first class—**common brown coal or fire coal**—forms compact masses, having a conchoidal fracture, and a light or dark brown colour. The broken surface has a dull or slightly-glazed appearance. It is classed between earthy brown coal and bituminous coal.

The second class—**earthy brown coal, small coal, or bituminous earthy brown coal**—occurs in more or less easily broken masses of yellowish, light to dark brown or brownish-red colour. The fracture is dull and uneven, devoid of organic structure, and rough to the touch.

The following varieties belong to this class:—

(*a*) *Paraffin coal*—a very light-coloured description, used for the production of burning oil and paraffin.

(*b*) *Grease coal*—used for making briquettes.

(*c*) *Aschengrund*—from the marshes in mining districts. The ash is utilised as manure.

(*d*) *Cologne umber or Cologne earth*—employed as a pigment and dyestuff.

(*e*) *Lampblack coal*—a coal occurring in Bohemia.

To the third class belong **lignite, woody brown coal, fibrous brown coal, or bituminous wood**, occurring as woody masses, more or less fossilised, and yellow to dark brown in colour. Degree of hardness, 1 to 2; specific gravity, 0·6 to 1·4. Fracture according to the character of the wood. Varieties: (*a*) Bast coal, and (*b*) Needle coal.

Class 4 includes **slate coal**, a dense, slaty, brownish-black to black coal, of uneven fracture.

Class 5 comprises **paper coal, dysodil, stinking coal,** and **foliated shale.** This easily separates into laminæ as thin as paper, pliable but tough, and is grey to dark brown; dull or shiny. Hardness, 1. It contains portions of plants, also well-preserved insects, fishes, frogs, crocodile remains, and feathers, but is considered to be of vegetable origin.

Class 6. **Leaf coal** or **foliated coal**—formed of superimposed layers.

Class 7. **Reed coal**—found in long reedy bands.

Class 8. **Moor coal,** which shows no wood-like structure, and has a flat, conchoidal fracture. It is usually soft and friable, but is occasionally hard and slate-like. In colour it varies between dark brown and pitch black, and has a dull appearance. Its specific gravity is 1·2 to 1·3. Hardness, 2·5. It frequently contains remains of marsh plants. Moor coal generally accompanies lignite deposits, and is found under and between the strata of this formation.

Class 9. **Pitch coal** or **specular coal**—compact, more or less brittle, and occasionally tough, but seldom hard. Dark brown to pitch black, with a waxy or somewhat pitchy gloss. Fracture imperfect, sometimes flat, conchoidal. Powder, brown. Hardness, 2·5. Specific gravity, 1·2 to 1·3. Pitch coal occurs sometimes alone, sometimes as layers in the strata of common brown coal or the earthy brown coal beds, and is found in the vicinity of eruptive, igneous rocks.

Class 10. **Gloss coal**—compact, deep black, with conchoidal fracture well developed, with a resinous to glassy and metallic lustre. This is the hardest and most compact of the brown coals. Hardness, 2·5 to 3. Specific gravity, 1·2 to 1·5.

Class 11. **Jet, azabache, gagat, black amber.** The name "gagat" is derived from the river Gages, in Lycia, at whose mouth this substance occurs. A dense, jet-like coal, with conchoidal fracture, so hard and firm that it can be filed and polished for ornaments.

Class 12. **Stem** or **columnar brown coal,** occurring as 4- to 6-sided columns, of a brown colour. Somewhat harder than common brown coal, but otherwise possessing similar characteristics.

The brown coals vary in composition with their appearance and occurrence, the bituminous, light-coloured, earthy brown coal of Saxony differing from the columnar coal of Meissner, &c.; the lignite of Westerwald from the gloss coal; and the dark-coloured brown coal of

Mertendorf, Prussia, from the pitch coal of Echelsbach in Bavaria. Generally, the Eocene coals contain relatively more carbon than those of the Miocene and Pliocene ages, the latter, however, having more oxygen than the former. If several strata occur in a bed, they seldom contain coals of identical character; usually there is more or less difference in appearance and composition, and a similar variation is even observed in the same stratum.

TABLE LI.—COMPOSITION OF BROWN COALS.

OCCURRENCE AND DESCRIPTION OF COAL.	Specific Gravity.	Carbon.	Hydrogen.	Oxygen and Nitrogen.	Sulphur.	Ash.	Hygroscopic Water.	Analyst.
Prussian Coals—		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
Meissner, Gloss Coal,	1·30	82	4·20	5·90	3·90	4	...	Craeger.
,, Pitch Coal,	1·20	62·18	5·47	18·05	9·30	5·60	...	,,
Siebengebirge, Ord. Brown Coal, .	...	77·10	2·54	19·35	...	1	...	Karsten.
Cologne, Umber, .	2·20	66·42	4·98	17·11	...	5·49	...	,,
Reistädt, Lignite, .	1·10	61·13	5·09	31·95	...	1·83	...	F. Bischoff.
Voigstädt, Earth Coal.	1·24	49·15	4·45	32·25	...	14·15	49·20	,,
Westerwald, Lignite,	...	70·26	6·40	21·40	..	1·90	48·50	Casselmann.
,, Leaf Coal,	...	62·80	6·70	17·30	...	11	24·60	,,
,, Paper Coal,	...	62·50	6·76	19·43	...	11·01	...	,,
Perleberg, Earth Coal,	...	64	5	27·50	...	3·30	17·30	Heintz.
Bavarian Coals—								
Echselbach, Pitch Coal, . . .	1·30	73·84	3·91	12·25	1·60	8·32	...	Schafhaütel.
Regensburg, Lignite,	...	63·70	5·80	29·40	...	0·90	45·60	Till.
Austrian Coals—								
Wildshut, Lignitic Brown Coal, .	1·30	53·79	4·26	25·39	0·98	15·58	26·15	Schrötter.
Thallern, Blackish-brown Lignite, .	1·41	49·50	3·81	22·68	4·56	19·34	22·58	,,
Grünbach, Specular Coal, . . .	1·15	73·79	7·46	15·56	4·96	...	...	Heintz.
French Coals—								
Bouche du Rhône, Earthy Brown Coal,	1·25	63·89	4·58	18·98	...	13·43	...	Regnault.
Basses' Alpes, Earthy Brown Coal, .	1·27	70·02	5·20	27·77	...	3·01	...	,,
English Coals—								
Bovey, Brown Lignite,	1·12	66·31	5·63	22·86	2·36	2·27	34·66	Kane.
Mull, Gloss Coal, .	1·20	76·21	6·04	17·75	...	...	...	,,
American Coals—								
Rocky Mountains, Gloss Coal, . .	1·20	56·50	3·24	14·41	0·42	15·93	14·50	...

The nitrogen varies from 0 to 2 per cent.

TABLE LII.—ASH CONSTITUENTS OF VARIOUS BROWN COALS.

SUBSTANCE.	ARTERN, Lignite.	HELNASTEDT Ordinary Brown Coal.	CROSS PRIESSEN.	MEISSNER, Lignitic Coal.	OBERKAUFUNGEN, Earthy Coal.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Potash, ...	0·99	...	1·67	1.90	0·90
Carbonate of Potash, .	...	2·64	...	...	...
Soda, ...	1·72	...	1·86	...	0·60
Lime, ...	20·56	23·67	45·60	10	18·70
Magnesia, . . .	2·16	2·58	...	3·40	2
Alumina, ...	29·50	11·37	1·23	14·70	32·20
Oxide of Iron, . .	32·78	5·57	20·67	18·10	8·90
Silica, ...	3·12	17·27	...	20·50	24·10
Sulphuric Acid, .	9·17	33·83	15·45	30·30	12
Carbonic Acid, . .	...	...	13·52	...	...
	100·00	100·00	100·00	100·00	100·00
Analyst, . .	Kremers.	Varrentrap.	O'Köttig.	Neiderstadt.	

The specific gravity of the true brown coals, with the exception of the Cologne Umber, varies between 0·8 and 1·15, and can only be considered as indicative of the density when the coal is free from foreign substances. In estimating this constant, air must be completely removed.

The freshly-won coals of the earthy varieties contain up to 50 per cent. of hygroscopic moisture, part of which is yielded up on exposure to the air, leaving behind 20 to 30 per cent., which is only driven off at 100° C. A coal so dried will quickly take up 8 to 12 per cent. of moisture on exposure to the air.

Air-dried brown coal has the following approximate percentage composition (neglecting the varying amount of the ash):—

Carbon, ...	48 to 56 per cent.
Hydrogen, ...	1 to 2 ,,
Water, in combination, . .	31 to 32 ,,
Hygroscopic moisture, . .	20 ,,

In combustibility, brown coal is inferior to wood, and in facility of ignition, between wood and hard coal.

The uses of brown coal as fuel are more limited than those of hard coal, as it cannot be employed for such purposes as hard coal is peculiarly fitted for. Its chief consumption in this way is for roasting furnaces in chemical works and salt works, and for domestic use. Frequently, the earthy variety is fit for fuel only after being compressed into blocks. Practically, it is found that freshly-mined brown coal is better for burning than that which has been exposed to the air for some time. The most important of its uses is in the production, by destructive distillation, of mineral oils and paraffin.

Brown coals which, during formation, have either lain between beds of clay or have been mixed with clay, shell limestone, or pyrites, are unsuitable for the mineral oil industry, being unusually rich in carbon and oxygen, and poor in hydrogen. The resulting tar is of very high specific gravity, and generally contains little paraffin. The most important factors in a tar coal are a high percentage of hydrogen and a low content of oxygen, and these differences in composition from *ordinary* brown coal are observable not only in coals from different sources, but where both occur in the same bed, the burning coal containing about 5·5 per cent. of hydrogen, and 25 to 30 per cent. of oxygen, as compared with 10·5 per cent. of hydrogen, and 13 to 21 per cent. of oxygen found in tar coal.

Before being employed in the manufacture of mineral oils, brown coal should be subjected to a preliminary analysis by destructive distillation. Dried coals yield proportionately more tar than newly-won coals, but the temperature of the drying air should not exceed 30° to 40° C., as many coals lose an appreciable quantity of bitumen even at a moderate heat.

Brown-coal tar is of a buttery consistency at ordinary temperatures, and solidifies at about + 5° C. Its colour is light, varying, however, with the coal from which the tar is distilled, but it becomes darker on exposure to heat and air, and under the influence of light the tar quickly turns black. The tar sometimes exhibits an acid and sometimes an alkaline reaction. The tar yields, on distillation, the following fractions:—

			Specific gravity.
From 130° to 170° C.,	Brown coal benzine,		0·710 to 0·750.
„ 170° to 220° C.,	Light brown coal-tar oil,	Photogen,	0·750 to 0·820.
„ 220° to 290° C.,	Heavy brown coal-tar oil,	Solar oil,	0·820 to 0·880.
„ 290° to 320° C.,	Lubricating oil,		0·880 to 0·900.
Above 320° C.,	Paraffin oil,		0·890 to 0·910.

These fractions are treated with acid and alkali to remove impurities, the fractions of higher specific gravity—viz., the lubricating and paraffin oils—being subsequently cooled to 3° to 5° C. by a freezing mixture, to crystallise the paraffin scale, which is then pressed to remove the oil.

The brown coals best suited for distilling and giving the largest yield, are the whitish, and brownish-yellow, pulverulent "paraffin" coals. Their average yield varies between—

	Per cent.		Per cent.
Coke, ...	25 to 60	Tar water, ...	20 to 40
Tar, ...	2 to 10	Gases, ...	5 to 25[1]

100 parts of tar yield on an average—

	Per cent.		Per cent.
Brown coal benzine, . .	2 to 6	Paraffin, ...	1·5 to 12
Photogen, ...	8 to 30	Asphalt, ...	14 to 20
Solar oil, ...	12 to 50	Gases, ...	3 to 10
Lubricating oil, . .	15 to 30	Water, ...	5 to 20

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[1] Or per kilogramme 0·12 to 0·35 cubic metre.

TABLE LIII.—Products of Distillation of Brown Coal.

100 parts of Brown Coal from the Pit yield	Coke.	Tar water.	Tar.	Sp. gr. of the tar.	Gases.
	Per cent.	Per cent.	Per cent.		Per cent.
(*a*) Oranien, mixed pieces, .	31·97	44·72	5·37	1·043	17·94
(*b*) „ large lumps, .	34·86	40·77	3·18	0·952	21·17
(*c*) Nassau, mixed pieces, .	31·28	43·69	3·78	1·064	21·29
(*d*) „ large lumps, .	31·22	43·07	2·86	1·041	22·80
(*e*) „ undried lignite,	34·21	42·83	5·61	1·079	17·35
(*f*) Oranien, dried lignite, .	36·42	...	5·88	1·072	12·60

The mixed pieces varied from 25 grms. to 300 to 400 grms.
The large lumps were from 7 to 20 kilos.

100 Parts of the above Tars yielded	Light Oil.	Heavy Oil.	Asphalt.	Water and Gases.
	Per cent.	Per cent.	Per cent.	Per cent.
a	30·53	7·63	13·48	48·37
b	26·60	18·83	13·64	40·90
c	48·79	12·42	24·24	13·55
d	37·06	9·10	17·80	36·33
e and f	51·29	19·80	19·80	9·11

—*R. Fresenius.*

TABLE LIV.—Giving other Results as to the Yield of Tar, &c.

The Name of the Analyst is given in each case.

100 parts Brown Coal from the Pit yielded from	Tar.	Specific gravity of Tar.	Crude Distillate. Specific gravity up to 0·850	Crude Distillate. Specific gravity 0·850 to 0·900.	Crude Paraffin.
	Per cent.		Per cent.	Per cent.	Per cent.
Tscheitsch in Mähren, woody, . . .	4·70	1·095	0·43	1·37	0·15
Tscheitsch in Mähren, older formation, .	3·50	1·050	0·32	1·89	0·18
Eger in Bohemia, .	7·50	0·915	0·55	3·75	0·50
Krzemusch in Bohemia,	0·50	0·920	1·08	3·22	0·30
Herbitz „	5·70	0·900	1·15	2·41	0·30
Schoebritz „	4·70	0·900	1·04	2·30	0·20

—*C. Müller.*

TABLE LIV.—*Continued.*

100 parts Brown Coal from the Pit yielded from	Tar. 0·88 to 0·97 Specific gravity.	Coke.	Ammonia Water.	Gas and Loss.	100 parts of Tar yielded				
					Light Oil. Specific gravity 0·820.	Lubricating Oil. Specific gravity 0·870.	Paraffin.	Asphalt.	Carbolic Acid and Loss.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Frankenhausen, . . .	5·57	50·36	26·47	17·60	33·40	40	6·70	17·30	2·40
Aschersleben, . . .	12	61·46	21·14	15·40	33·50	40	3·30	18·10	5
Stockheim, near Düren, .	6·24	36·26	49·58	9·92	17·50	26·60	3·20	16·90	36·70
Cassel, ...	5	36·25	42·50	16·25	16·40	27·10	4·30	14·30	37·80
Münden, ...	2·92	31·39	50	15·69	17·50	26·20	5	18·60	32·50
Oldisleben, ...	6·10	29·37	56·25	8·28	17·70	26·60	4·40	17·50	33·70
Herbke, ...	4·23	30·10	50	15·67	15·50	11·10	3·50	22·20	47·50
Tilleda,.	1·80	20·60	70	7·60	16·60	18	4·40	11·10	49·70
Bensberg, near Cologne, .	4·45	31·39	50·16	14·06	16·30	19·50	3·40	13·10	47·40
The Rhone, ...	0·88	46·66	41·25	10·64	10·60	19·30	1·20	16·90	51·80

—*H. Vohl.*

100 parts Brown-Coal Tar yielded	Light Oil. 0·75 to 0·86.	Lubricating Oil. 0·86 to 0·95.	Paraffin.
	Per cent.	Per cent.	Per cent.
Lignite from Reichenbach, in Bohemia, .	2	50·70	25·90
,, Linz, ...	8·40	40·70	26·30
Brown coal from Gröbero, ...	7·13	55·29	38·50
,, Döllnitz, ...	5·05	32·57	40·40
,, Halle, ...	7·90	32·90	39·15
,, Lehmdorf (light brown), .	11·80	31·20	36·40
,, ,, (dark brown), .	8·90	33	34·40
,, ,, ,, .	10·90	32·80	37·50

—*Hübner and Vœrckel.*

100 parts Leaf Shale yielded	Tar. Specific gravity 0·88 to 0·93.	Crude Distillate Specific gravity 0·70 to 0·85.	Crude Distillate Specific gravity 0·85 to 0·90.	Crude Paraffin.
	Per cent.	Per cent.	Per cent.	Per cent.
Siebengebirge, . .	20	6	9	0·75
,, . .	15	5	7	0·50
,, . .	11	3	6	0·50
Hessen, . . .	25	6	12	1
Rhine provinces, . .	11	3	5	0·50
Bonn, ...	5	0·10	3	0·25

—*Wagenmann.*

TABLE LIV.—*Continued.*

100 parts Leaf Shale yielded	Light Oil (Phogoten). Sp. gr. 0·820.	Heavy Oil (Lubricating Oil). Sp. gr. 0·860.	Paraffin.	Asphalt.	Carbolic Acid and Loss.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
English leaf shale,	24·28	40	0·12	10	25·29
Rhenish ,,	25·68	43	0·12	12·03	19·16
Westphalian ,,	27·50	13·67	1·12	12·50	45·30
Oedingiau ,,	18·33	38·33	5	13·33	25

—*H. Vohl.*

The Rhenish shale contained so much arsenic as to injuriously affect the workmen in the refinery.

The Rhenish **leaf shale**, or so-called **paper coal**, yielded—

Air-dried Coal.	
Tar, ...	20 per cent.
Coke, ...	46·33 ,,
Gases, ...	9·45 ,,
Tar water, . . .	24·22 ,,
	100 ,,

Tar.	
Photogen, . .	32·50 per cent.
Solar oil, . .	0·33 ,,
Paraffin cake, .	51·25 ,,
Carbon, . . .	8·92 ,,
Loss, . . .	1 ,,
	100

—*H. Vohl.*

Bentheim **gagat** yielded the extraordinary quantity of 45 per cent. of an aromatic transparent tar of the colour of rape oil, which solidified at 10° C.

Gagat Tar.	Specific gravity.	Boiling point.	Per cent.
Lightest oil, . . .	0·70 to 0·75	70° to 120° C.	6
Light oil, ...	0·75 to 0·82	120° to 250° C.	30
Heavy oil, ...	0·82 to 0·86	250° to 350° C.	30
,, ...	0·86 to 0·88	Over 350°	15
Coke, water, and loss, .	...	...	19
			100

—*Knapp.*

The **tar** is obtained from brown coal or lignite by a process of slow distillation, and the product is fractionally distilled and purified somewhat as shale oil is treated. The treatment and composition of the tar have recently been carefully investigated by Edgar von Boyen,[1] T. Heusler,[2] and others.

The tar differs widely from the petroleum oils, and, although more nearly resembling shale oil, is still so far distinct as to require different treatment. According to von Boyen, if the portion of the lignite tar oil boiling at over 300° C., and freed as far as possible from crystalline paraffin, be distilled, and after treatment with acid and alkali be redistilled, the temperature will be observed to rise slowly and regularly without break, and fractions taken at every 5° will be found to have a close resemblance to each other. The specific gravity and viscosity increase with the boiling point, and the colour deepens, but the odour becomes less strong. If one of these fractions be agitated with 50 per cent. of concentrated sulphuric acid at ordinary temperatures, an equal quantity of the oil dissolves, with the formation of a red-brown or black solution, from which a black mass, technically known as saüreharz (acid sludge), separates. This substance is not resinous, but is a mixture of sulphonic acids, which are readily soluble in water. The acid agitation may be repeated with the same result, until little of the oil is left unacted on, and this differs but little from the original oil, though it is generally of lower density. If only 3 per cent. of concentrated sulphuric acid be used, the black mass obtained is more like resin, the "sludge acids" from tar or crude paraffin being thick and sticky, and but slightly soluble in water. The products obtained by further treating the oil with acid, are soluble in water. The remaining oil forms, with water, a milk-white emulsion, from which an oil of below 0·900 specific gravity separates, after standing in a warm place, but no separation of oils of over 0·900 specific gravity occurs even after a week. Fuming acid has the same effect; but crystalline sulphonic acids, or their salts, are not obtainable from the sludge acid. Concentrated nitric acid gives a brisk reaction, red resinous bodies being produced on warming. The fuming acid dissolves the oil to a clear red solution, from which amorphous resins separate on the addition of water. They are easily soluble in hot alcohol, but are precipitated on cooling, in a powdery or resinous form, according to the action of the acid, but never in crystals. Von Boyen considers that these reactions conclusively show the absence of paraffins. When heated with caustic potash, the greater part of the oil volatilises unchanged, the remainder forming a black mass. With a mixture of potassium chromate and sulphuric acid, the oil thickens and turns red. Acetic acid is produced by oxidation with potassium permanganate in an alkaline solution. These reactions show a great difference between the composition of the lignite paraffin oils and petroleum oils.

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[1] *Chemiker Zeitung*, xiv., 267 and 289, and *Zeits. f. Angew. Chemie*, 1891, 101 and 261.

[2] *Ber. d. d. chem. Gesellsch.*, 1892, xxv., 1665.

The refining of the oils below 0·900 specific gravity is not attended with difficulty, and is similar to that of the heavier oils. Those of over 0·900 specific gravity boil, as a rule, above 300° C., mostly, indeed, above 360°, and such an oil as is obtained in manufacture from Tertiary deposits, when distilled experimentally, yields first a small quantity of water, accompanied by products having an odour of garlic, and a yellow organic body redolent of sulphur products, which collect in the condenser tube. The first distillates have the strongest smell, but the last have an odour of acroleïn, even when distilled *in vacuo*, which is not perceptible when the distillation is conducted on a large scale. The colour of the distillates deepens with each successive fraction. These changes are due to the high temperature, and not to oxidation, and the use of superheated steam improves the colour. The heaviest oil prepared on a large scale is separated from the soft paraffin scale, and this oil seldom has a specific gravity exceeding 0·920, or a viscosity of more than 3·60, by Engler's test.

The following table shows the result of the distillation of a thick dark-green oil, of specific gravity 0·945 at 14° R., which had been freed from creosote by treatment with 5 per cent. of soda lye. The distillation was conducted with the aid of superheated steam, 0·5 per cent. of soda lye having been previously added:—

	Kilos.	Specific gravity at 14° R.
First Runnings,	224	0·881
Mixture,	1624	0·933
Red Product I.,	224	0·956
„ II.,	140	0·968
„ III.,	100	0·988
Total and average,	2312	0·935

The distillate was pale yellow up to 0 956.

The 1,624 kilos., when fractionated into seven portions, gave:—

	Specific gravity.	Viscosity (Engler).
Fraction I.,	0·900 at 14° R.	2 692 at 14° R.
„ II.,	0·926 „	4·385 „
„ III.,	0·932 „	5·308 „
„ IV.,	0·935 „	5·770 „
„ V.,	0·937 „	6·923 „
„ VI.,	0 943 „	8·404 „
„ VII.,	0·956 „	11·535 „
Average,	0·935 „	5·770 „

It is well known that the hydrocarbons of lignite tar oils are capable of converting oxygen into ozone, and are thereby bleached—a property also shared by the paraffins, and first observed by L. Grotowsky in the case of solar oil.[1] Refined brown-coal tar oil, even when protected from air and sunlight, becomes dark coloured after a couple of months. Similar oil treated with soda lye and placed in the sun will darken quickly at first, but bleaches in a few days—oils of low density changing more quickly than heavier ones.

[1] *Zeits. f. Berg-Hütten und Salinenwesen*, 24, 381.

The oil after acid treatment behaves quite differently, and bleaches rapidly, away from sunlight. It is difficult to account for this, as the removal of the sulphonic acid compounds produces no change, and it can only be attributed to the sulphuric acid, although its action is not as yet understood.

Air is not necessary for the bleaching, though where the oil contains water, the vessels should be left open. Two samples, one sealed and the other open, taken from the same oil, which had stood in a warm dark place for about a fortnight, bleached equally from deep red to light yellow after about two hours' exposure to sunlight. The best vessels for bleaching in sunlight are of white glass, either flat and shallow, or upright, so that the light only has to pass through a thin layer of oil. The bleaching-room should be kept at 20° to 25°, the air dry and free from dust, and the vessels should be so arranged that the direct rays of the sun fall on them, reflected light not being so effective. When the bleaching is finished, a thick dark sediment collects at the bottom of the vessels. The oil is then removed from the direct sunlight, as otherwise the continued ozonising would result in the production of acetic acid and homologues, which would impart a sour odour without improving the colour.

Distillation.—In the vacuum process, there is less decomposition and loss of oil than occurs when the distillation is conducted in the ordinary manner. High-pressure or superheated steam does not give particularly favourable results, and the condensed water is separated with difficulty.

Acid Treatment.—The action of concentrated sulphuric acid on the lignite tar oils is unlimited. The results of a number of experiments made with a view of ascertaining the best proportion of acid to use, indicate that this should be from 2·5 to 4 per cent. of 66° B. acid, or less of fuming acid.

Before being treated with acid, the distilled oil should be freed from water. It should be clear, and not deeper in colour than cherry red when viewed in a thickness of 10 centimetres. The temperature of the oil to be treated should be about 10° C., and must not exceed 20°, as, although the action of the acid is, under any conditions, to remove the unstable portions of the oil, yet at the higher temperature, the sludge acids also react on the oil, producing sulphur dioxide and water. The presence of the latter greatly hinders the separation of the black specks in the oil. A number of experiments made in the endeavour to remove this water from the oil gave negative results, hygroscopic substances such as magnesium chloride and calcium chloride, even in a finely-divided state, having little effect. Even after neutralisation of the acid, these agents fail to clarify the oil, the best result being obtained by using fine clay for the purpose.

The acid or alkali treatment is most effectually carried out in an air-blast agitator. After the acid treatment, the oil, still dark-coloured and opaque, is mixed with strong soda lye at a moderate temperature, and is allowed to stand for a day to remove creosote, &c. It is then distilled in fractions of 5 degrees of the 1,000-degree areometer, cooled to below 20°, and re-treated with 3 per cent. of acid of 66° B., for fifteen minutes, in the air-blast agitator, care being taken to have both the oil and the air-blast thoroughly dry. Fuming acid is preferable to the 66° B. strength for the final operation, as a smaller quantity suffices, and it is found that the less acid used, the more easily is the clarification subsequently effected.

After settling and removal of the sludge acid, treatment follows with finely-powdered and sifted unctuous clay, freed from water and organic substances. This attracts and carries down the black acid particles. Poor or badly-sifted clay is worse than useless, as is also burnt clay. The manipulation is also important, and care must be taken to avoid an excess, which is prejudicial. The clay meal must be added gradually, in small and decreasing quantities. A little sludge acid should be left in the agitator with the oil, as its presence facilitates the conduct of the cleansing process. After agitation for about fifteen minutes to half an hour, the oil suddenly becomes pale yellow in colour, and after settling, must be drawn off very carefully to avoid disturbing the sediment.

After testing a sample with concentrated soda lye to ascertain the smell, which is the best indication of the condition of the oil, the whole is mixed with 1 to 2 per cent. of concentrated soda lye at a moderate temperature, and is kept at 40° to 60° C. until clear (generally 24 hours is sufficient), after which the sediment is carefully removed, and the oil cooled to 20°, to prepare it for a repetition of the acid process. This consists of treatment with 4 per cent. of acid and 3 per cent. of clay in two mixings, followed by washing, and, if necessary, redistillation and further treatment.

To remove the sulphonic acids, a washing process is necessary, during which these acids form a milky emulsion. The oil also enters into these emulsions, and can only be recovered by heating, but this injures the colour. In fact, the oil recovered from the first washings is of poor quality, and not worth the trouble of separation. The most economical way of treating the oil after the washing, if the colour has become dark, is by a final agitation with sulphuric acid and clay, followed by neutralisation with finely-powdered sodium carbonate, which combines with the sulphonic acids, to form flaky or gelatinous salts, insoluble in the oil. The process is finished when frothing occurs, and the oil is found to be of a pale citron-yellow colour. A medium temperature is best for the operation, and about one and a-half hours suffices, on an average, to produce the desired result. It is preferable to wash the oil after two acid treatments, as otherwise there is difficulty in getting the oil clear by the dry process. The sulphonic compounds must also be removed before distillation, or compounds of disagreeable smell will come over with the oil.

The storage of the oil, before treatment, should be effected in the open, in shallow iron reservoirs protected from dust and dirt. Rain and air have, in time, a considerable oxidising effect, and the more volatile, strong-smelling oils are volatilised. The refined oil should be kept in vessels with small exposed surface. Glass or leaden receptacles are the best, the former being preferable. Iron, even when free from rust, is a carrier of oxygen, and affects the colour, and wood is also prejudicial. The vessels must not be closed, but must permit the escape of gas and water vapour. There should be a tap at the lowest point for the removal of sediment.

The following account of the work of Heusler, on the brown-coal tar oils obtained at the Riebecksche Montanwerke, is taken from the *Journal of the Society of Chemical Industry.* Not only were the commercial distillates examined, but also the fractions of low boiling point, which are, in practice, allowed to escape as vapour:—

"The distillates were washed with dilute acid and alkali to remove all basic and phenoloid substances. They were then fractionated by means of steam, carefully dried by potash, and at last repeatedly fractionated in copper stills. Both Linneman's and Norton-Otten's dephlegmators were used, the latter yielding better results than the former. Mere fractionation seemed unlikely to yield pure substances, since above 180° a partial decomposition of the hydrocarbons appeared to occur.

"The following methods were, therefore, resorted to:—

"1. METHOD OF PARTIAL OXIDATION.

"Wagner's process of oxidation of non-saturated hydrocarbons by means of an alkaline solution of potassium permanganate,[1] was thought of for separating the saturated hydrocarbons from the non-saturated ones, the latter becoming changed into glycols. Before, however, Wagner's method was followed, the author tried partial oxidation by means of permanganate in an acid solution. The oxidation of the fractionated oils, mixed with sulphuric acid, seems to take place readily at first, but at last a stage is reached when the permanganate is only slowly decolorised. At this moment, the further addition of permanganate is discontinued, and the unattacked hydrocarbons are conveniently separated by distillation in a current of steam. There remains in the distillation flask a resinous mass, whilst the hydrocarbons entirely differ in their behaviour from the original tar oils. In the first instance they are free from the peculiar, disagreeable smell of the brown-coal tar oils; next, their boiling point is found to have considerably decreased. Whilst the lower-boiling crude oils are most violently acted on by nitric acid, the hydrocarbons left after the oxidation, as specified, may be easily oxidised—just like coal-tar hydrocarbons—yielding a heavy oil, which is partly soluble in caustic soda, with an intense reddish-brown colour. The insoluble part consists of the nitro-derivatives of aromatic hydrocarbons.

"2. METHOD OF PARTIAL BROMINATION.

"The crude oils were dissolved in absolute ether, and bromine was added until an evolution of hydrobromic acid was noticeable. It may be assumed that at this moment all the non-saturated substances had directly absorbed bromine, and that a substitution in the molecule of the saturated substances had commenced to take place. On evaporating the ether and distilling in a current of steam, at first a light oil was obtained; later on, a heavy oil—the bromo-addition product of the non-saturated hydrocarbons—passed over. The light oils are essentially a mixture of aromatic and saturated aliphatic hydrocarbons.

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[1] *Journ. Soc. Chem. Ind.,* 1892, 135.

"3. Action of Sulphuric Acid of varying Strengths.

"Concentrated sulphuric acid acts on the brown-coal tar oils with evolution of large quantities of sulphurous acid. A diluted acid, however (2 parts of oil of vitriol and 1 part of water), dissolves certain substances from the oils without giving rise to the formation of sulphurous acid. The author washed the tar oils twice with sulphuric acid. After siphoning off the acid solution, the residual oily layer was washed and distilled. The oils thus obtained had a lower boiling point than the original oils, and behaved towards nitric acid just like the oils recovered by the oxidation process. On shaking them with concentrated sulphuric acid at the ordinary temperature, sulphurous acid is evolved; on cooling, however, the liberation of sulphurous acid may be prevented. The remaining oils (after the washing with concentrated sulphuric acid) seemed to consist of aromatic and saturated aliphatic hydrocarbons. The substances soluble in acid yielded, on being subjected to dry distillation, large quantities of sulphurous acid. The study of this reaction is reserved for further research; the possible presence of substances related to the thiophens is, however, hinted at.

"*Quantitative Estimation of the Aromatic Hydrocarbons belonging to the Benzene Series.*—The hydrocarbons obtained by the processes 1 and 3 were examined more closely. An acid-washed fraction, boiling from 80° to 93° C., was nitrated, and the resulting nitrobenzene identified by transforming it into dinitrobenzene. This fraction was found to contain about 34 per cent. of benzene, which is, in the author's opinion, certainly too low. The nitric acid solution from which the nitrobenzene had been separated contained solid fatty acids, the greater part of which consisted of oxalic acid. A fraction of oils boiling between 100° and 110°—obtained by the first process—contained 45 per cent. of toluene, estimated by the crystallised dinitrotoluene. *m*-Xylene and mesitylene were found in higher boiling fractions, and identified by the trinitro-*m*-xylene and the trinitromesitylene. The fraction of oils boiling from 135° to 140° C., contained about 30 per cent. of aromatic hydrocarbons. The author concludes that the percentage of aromatic hydrocarbons of the benzene series decreases with the rising of the boiling points.

"*Quantitative Estimation of the Aliphatic Saturated Hydrocarbons.* A careful examination of the oils unacted upon by nitric acid showed that Markownikow's naphthenes were completely absent. The following table gives the percentages of saturated hydrocarbons in the oils which had been previously oxidised by means of permanganate:—

Fraction.	Boiling Point.	Saturated Hydrocarbons.
	Degrees C.,	Per cent.
I., ...	90 to 100	14·50
II., ...	135 to 140	17·25
III., ...	140 to 145	18·00
IV., ...	145 to 150	19·75
V., ...	150 to 155	20·25
VI., ...	155 to 160	21·50

"The amount of saturated hydrocarbons increases as the boiling point rises.

"*Terpenes* could not be detected in the brown-coal tar oils, although the author carefully searched for them, using the methods suggested in Wallach's researches on the terpenes. Heusler especially looked for pinene and dipentene,[1] but, as stated, in vain.

"*Indene* and *cumerone*, which have been shown to be present in coal-tar oils,[2] were also absent.

"*Naphthalene*, however, was found in a fraction boiling from 180° to 240° C., and identified by means of its picrate, from which pure naphthalene was isolated. The percentage of this hydrocarbon amounted to at least 4 or 5 per cent."

Kimmeridge Shale.—Extensive deposits of bituminous clays, attaining in places to a thickness of as much as 600 feet, occur in Dorsetshire. These deposits, which take their name from the village of Kimmeridge, in the Isle of Purbeck, were worked as early as the sixteenth century, as a source of alum. More than 40 years ago, a company was formed under the name of the Bituminous Shale Company, to manufacture lubricating grease, pitch, naphtha, paraffin, varnish, and paint, as well as ammonia, by subjecting the shale to destructive distillation, and plant was erected at Weymouth. In 1854, the property changed hands, and the works were removed to Wareham, attention being concentrated upon the manufacture of manure. The process of distillation adopted yielded from a ton of the shale, 7½ gallons of naphtha, 10 gallons of illuminating oil, 12 gallons of lubricating oil, 120 pounds of pitch, 11½ cwts. of coke, and a small quantity of paraffin wax. At a later date, a new company was formed, mainly with a view to the production of mineral oils, and the works were reconstructed. This company was wound up in 1872, and in 1876 another was formed to introduce the carbonaceous residue obtained in the destructive distillation of the shale as a substitute for animal charcoal, but the operations of this new undertaking do not appear to have been financially successful.

Of the various seams, the richest in bituminous matters appears to be that which was termed the Blackstone. This bed is about 2 feet in thickness, and in laboratory experiments, the material gave 39 per cent. of oily and solid volatile products (2·3 per cent. of light oil or naphtha, and 36·7 per cent. of heavy oil containing 1·9 per cent. of paraffin), 18 per cent. of gas, water, ammonia, &c., and 43 per cent. of coke. In 1876, Mr. Patterson, of the Warrington Gas Works, reported that a ton of the Kimmeridge shale yielded an average of 67·25 gallons of crude oil (containing about 20 per cent. of naphtha and 3 per cent. of paraffin), 11 gallons of liquor containing 6 per cent. of ammonia, and from 1,118 to 1,187 lbs. of coke.

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[1] *Journ. Soc. Chem. Ind.*, 1889, 959; 1891, 788.

[2] *Ibid.*, 1890, 275; 1891, 38.

A few years ago, a quantity of this shale was mined at Portesham and distilled in Scotland, a yield per ton of about 50 gallons of crude oil and about 38 lbs. of sulphate of ammonia being obtained.

SECTION VIII.

THE TRANSPORT, STORAGE, AND DISTRIBUTION OF PETROLEUM.

Early Methods.—In the early days of the petroleum industry, the oil was transported in the most primitive manner. Thus, in Upper Burma it was conveyed in earthenware vessels from the wells to the river bank, where it was poured into the holds of boats. It is interesting to note that a rude pipe-line formerly existed at Yenangyaung for conveying the crude oil from the wells to the river. Writing in the *Burma Gazette* in 1874, Dr. Friedländer says:—"Worth mentioning here is also the oleoduct now in course of construction at Yenanchung, and a decided improvement upon the old mode of transport by chatties in carts. Wholly made up of bamboos, supported by wood stages (the inside lacquered), it runs with a gentle slope from the wells down to the river bank." Dr. Noetling states that this pipe-line was completed, but that, according to the natives, the loss by leakage was so great as to lead to its immediate abandonment.

In Russia, until 1875, the crude oil was carried in barrels on Persian carts known as "arbas." These are carts with two wheels of 8½ to 9 feet in diameter, and were used to a very large extent, as much as £100,000 per annum having been paid for the transport of the oil from the wells to the refineries. The body of the cart carried one barrel, and another was slung beneath the axle.

THE UNITED STATES.

In America, crude petroleum was first transported in iron-hooped barrels made of oak. These barrels, which held from 40 to 42 American gallons, were carried by teamsters to Oil Creek and the Allegheny river, at that time the only channels of conveyance to the refineries, at an enormous cost, amounting in some cases to as much as three dollars per barrel for a distance of four miles. Further difficulty and expense occurred during the river transport. The empty boats were towed up Oil Creek by horses which waded in the stream, and when loaded, were carried down whenever sufficient water was produced by a freshet, or could be obtained by damming the stream. Large numbers of boats were employed in this traffic, and as a whole fleet of them proceeded down the stream together, great loss from collision and grounding ensued. Henry[1] says that "as many as 40,000 barrels were brought out of the creek on one of these freshets, but the average

[1] *Early and Later History of Petroleum*, 287.

was between 15,000 and 20,000. At Oil City, the oil was transferred to larger boats. At one time over 1,000 boats, 30 steamers, and about 4,000 men were engaged in this traffic. . . . During the freshet of May, 1864, a jam occurred at Oil City which resulted in the loss of from 20,000 to 30,000 barrels of oil." To minimise loss of oil by leakage, the barrels were coated internally with glue, but this was attacked by the water always present in the oil, and considerable escape of oil still occurred. Bulk barges were soon introduced on the Allegheny and Ohio rivers, and Professor Peckham, writing in 1880, says:—"As now constructed, they are made 130 by 22 by 16 feet, in eight compartments, with watertight bulkheads, and hold 2,200 barrels. They are still used to convey oil from the lower Allegheny to the refineries at Mingo, Wheeling, Marietta, and Parkersburg, and also to float the production from Burning Springs down the Little Kanawha to Parkersburg."

In the latter part of 1862, the Atlantic and Great-Western Railway carried a branch into the oil regions, and soon after, a line was constructed up Oil Creek to Corry by the same company, thus directly connecting the district with New York and the West. The oil was at first carried on the railway in the ordinary barrels, but in 1865 or 1866, tank-cars were introduced, consisting of an ordinary flat car upon which were placed two wooden, tub-like tanks, each holding about 2,000 gallons. In 1871, these wooden tanks were replaced by horizontal cylinder-tanks of boiler-plate, similar to those now in use.

Pipe-lines.—The first suggestion for the construction of a pipe-line for transporting petroleum appears to have been made by General S. D. Karns, of Parkersburg, Western Virginia, who, in November, 1860, proposed to lay a 6-inch pipe from Burning Springs to Parkersburg, through which the oil would flow by gravitation to the Ohio river, a distance of 36 miles. This line was never made, but in 1862 Mr. L. Hutchinson, of New York, laid a line on the Tarr Farm to convey the oil over a hill to the refinery, on the siphon principle, and a year later constructed another, three miles long, from the Sherman well to the railway at Miller Farm. The latter line was provided, at intervals of every 50 or 100 feet, with air-chambers to equalise the pressure, but the principal defect which rendered this and the previous attempt unsuccessful, was the excessive leakage at the joints of the pipes.

The first successful pipe-line was laid in 1865 by Mr. Samuel Van Syckle, of Titusville, the main improvement being in joining the sections of the pipe by carefully-fitted screw-sockets. The pipe was laid two feet underground, and was four miles in length. In 1865 to 1866, Mr. Harley constructed a pipe-line between Benninghoff Run and Shaffer Farm, and later on, he founded the Pennsylvania Transportation Company, and constructed a pipe-line from the Pennsylvania oil fields to the seaboard.

Mr. J. H. Harris[1] gives the following as the cost of transportation as late as 1st December, 1865:—"By pipe-line from Pithole to Miller

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[1] *British Association Report*, 1885.

Farm, 4s. 2d. per barrel; barrelling, shipping, &c., at Miller Farm, 1s.; freight to Corry by railway, 3s. 4d.; freight from Corry to New York by Erie Railway, 14s. 6d.—making a total cost, for transportation, of 23s. per barrel. Or, by another route, transportation by pipe-line from Pithole to the Allegheny, 4s. 2d.; freight on the Allegheny to Pittsburg, 6s.; wharfage, loading, &c., at Pittsburg, 1s.; freight from Pittsburg to New York by Pennsylvania Railway, 9s. 3d.—total, 20s. 5d."

In 1875, a four-inch pipe-line about 60 miles in length was laid from the lower oil country to Pittsburg, and, by 1876, the opposition of teamsters and others having been overcome, mainly by rigorous punishment of those who tampered with the pipes, eight or nine distinct pipe-line companies were in operation in the oil regions.

Up to 1876, the oil was largely refined in the neighbourhood of the wells, but it was found that the important refineries at Cleveland, Pittsburg, Buffalo, Boston, New York, Philadelphia, and Baltimore, were better situated for the disposal of the burning oil and other products of distillation. The conveyance of crude petroleum to these centres, therefore, rapidly acquired such importance, that a combination was effected between the United Pipe Lines Company (comprising an association of the principal local lines), the Standard Oil Company of Cleveland, the American Transfer Company, and others, the National Transit Company being thus formed.

The trunk lines are now controlled by the National Transit Company, the Tide-Water Pipe Company, Limited, the Octave Pipe Line, the South-Western Pennsylvania Pipe Lines, the Eureka Pipe Line Company, the Buckeye Pipe Line Company, the Southern Pipe Line Company, the Charles Miller Pipe Line, the Western and Atlantic Pipe Line, the Elk Pipe Line, the Crescent Pipe Line (Mellon Line), the Producers' Pipe Line, the Producers' and Refiners' Oil Company, Limited; the United States Pipe Line (Emery Line), and the New York Transit Company. The first two mentioned are the most important.

The following account, derived from a report by Mr. Folger,[1] shows the extent of the various pipe-lines in 1892. The trunk line laid next after the line from the lower oil country to Pittsburg, already mentioned as laid in 1875, was a line to Cleveland, consisting of a 6-inch line from Bear Creek to Hilliards, the first pumping station, and from there a 5-inch line to Cleveland. The total length is about 111 miles. The trunk line to Philadelphia starts at Colegrove in M'Kean County, and extends about 235 miles to Philadelphia, 6-inch pipe all the way. From Millway, the last pumping station before reaching Philadelphia, a 5-inch branch runs down to Baltimore, a distance of about 66 miles. The Buffalo line is about 56 miles long, having its initial point at Olean, N. Y. It is 4-inch pipe. The New York line consists of two 6-inch pipes starting at Olean, N. Y., and running parallel to each other through the southern counties of New York State, to Saddle

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[1] "Petroleum: Its Production and Products," *Annual Report of the Bureau of Industrial Statistics, Pennsylvania*, 1893.

River, N. J., where the lines separate; one going down to the refineries at Bayonne, N. J., and the other going under the North and East Rivers to the refineries at Hunter's Point, on Long Island. In addition to the two parallel 6-inch lines, the New York line is

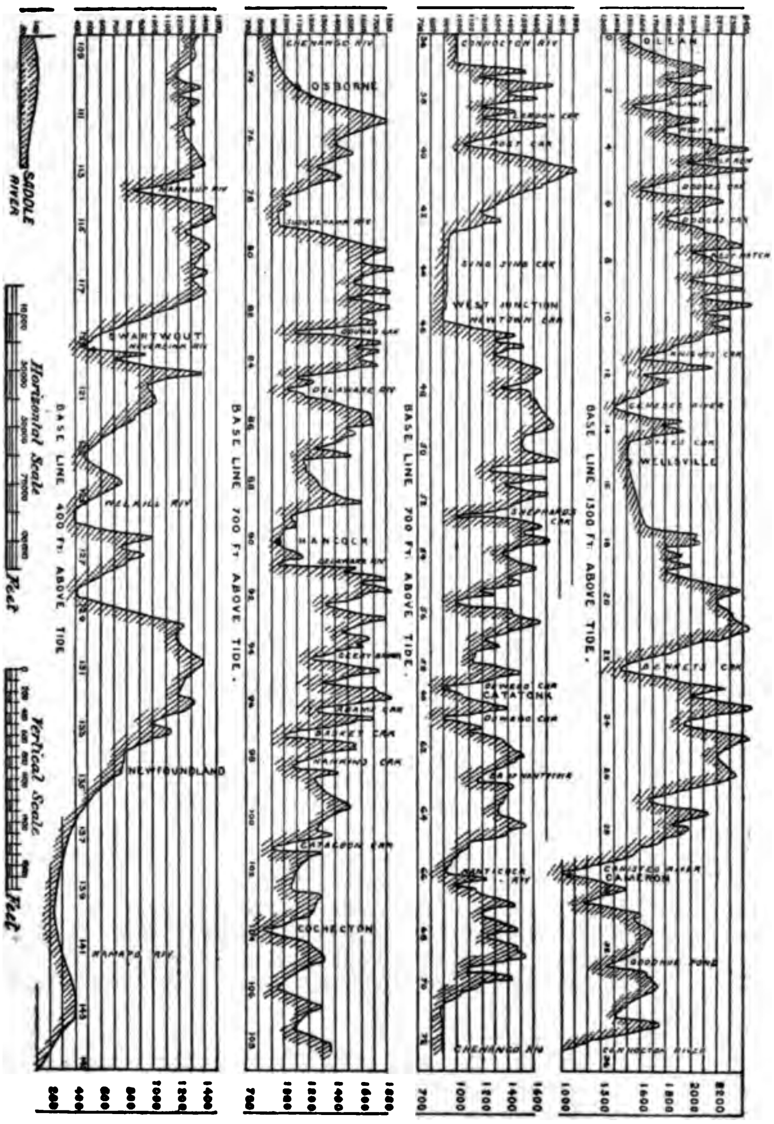

Fig. 168.—Profile of the Country traversed by the New York Pipe Line.

looped at many of the stations—that is, extra lines are put in to relieve the pressure on the other lines, and so increase somewhat their capacity—thus making the total length of pipe used 762 miles, the distance traversed by the line being 313 miles. Fig. 166 shows the profile of the country traversed by the line, the highest elevation above the tide-line being 2,490 feet.

The Tide-Water line of 6-inch pipe extends from Rixford in M'Kean County, to the refinery of the Tide-Water Oil Company, Limited, at Bayonne, N. J., a distance of 284 miles.

The Southern Trunk line starts from Morgantown, W. Va., and extends to Philadelphia, a distance of 274 miles. This line is composed of 6-inch and 8-inch pipe, the total length of pipe being about 364 miles.

The table below shows the actual length of each trunk line. In addition to these there are many other large lines connecting the various systems and different oil fields. For example, between Kane and Bear Creek, a distance of 63 miles, there are five 6-inch lines; from Kane to Colegrove, there are 22 miles of 8-inch pipe; from Colegrove to Olean, 30 miles of 8-inch pipe. The total length of pipe, including these large connecting lines and the double lines and loops, is nearly 3,000 miles.

Pittsburg Line, 4-inch pipe—		Miles.
Bear Creek to Pittsburg,		55
Buffalo Line, 4-inch pipe—		
Olean to Buffalo,		56·25
Cleveland Line, 5-inch pipe—	Miles.	
Bear Creek to Simpson,	29·81	
Simpson to Warren,	30·23	
Warren to Mantua,	22·16	
Mantua to Cleveland,	28·59	
		110·79
Philadelphia Line, 6-inch pipe—	Miles.	
Colegrove to Hunt's Run,	23·41	
Hunt's Run to North Point,	25·90	
North Point to Pine,	25·73	
Pine to Latshaw,	45·40	
Latshaw to Millway,	51·94	
Millway to Philadelphia,	62·50	
		234·88
Baltimore Line, 5-inch pipe—		
Millway to Baltimore,		65·80
New York Line, 6-inch pipe—	Miles.	
Olean to Wellsville,	28·54	
Wellsville to Cameron Mills,	27·91	
Cameron Mills to West Junction,	29·74	
West Junction to Catatonk,	27·37	
Catatonk to Osborne Hollow,	27·99	
Osborne Hollow to Hancock,	29·86	
Hancock to Cochecton,	26·22	
Cochecton to Swartwont,	28·94	
Swartwont to Newfoundland,	29·00	
Newfoundland to Saddle River,	28·77	
Saddle River to Bayonne, N. J.,	16·29	
Saddle River to Hunter's Point, N. Y.,	12·26	
Total (with loopings),		762·01

Tide-Water Line, 6-inch pipe—	Miles.	
Rixford to Olmstead,	28·7	
Olmstead to County Line,	36·0	
County Line to Muncy,	53·5	
Muncy to Shuman,	33·9	
Shuman to Hudsondale,	27·65	
Hudsondale to Changewater,	52·5	
Changewater to Bayonne, N. J.,	51·5	
		283·75

Southern Line, 8-inch and 6-inch pipe—	Miles.	
Morgantown to Watson,	33·88	
Watson to State Line,	35·82	
State Line to Knepper,	66·67	
Knepper to Millway,	75·42	
Millway to Philadelphia,	62·50	
Total (with loopings),		364·29

Crescent Pipe Line (*Mellon Line*), 5-inch pipe—	Miles.	
Greggs to Millbank,	about 48	
Millbank to Ingleside,	„ 24	
Ingleside to Saxton,	„ 30	
Saxton to Mount Holly,	„ 55	
Mount Holly to Florinal,	„ 40	
Florinal to Linwood,	„ 60	
		267

United States Pipe Line (*Emery Line*), double line, 4-inch and 5-inch pipe—	Miles.	
Titusville to Tarport,	about 65	
Tarport to Westfield,	„ 60	
Westfield to Athens,	„ 55	
Total (two lines),		360

Since Mr. Folger's report was written, the author has been informed by the Hon. Lewis Emery, jun., of Bradford, Pa., that the United States line has been extended from Athens to Wilkesbarre, a further distance of 64 miles, making a total of 488 miles. One of the lines is employed for transport of refined petroleum (kerosene).

In addition to the trunk lines carrying Pennsylvania crude oil, there is a network of 2-inch pipes that cover the producing country, and serve as feeders for the trunk lines.

Where the New York trunk line passes under the Hudson River, it is jacketted—that is to say, one pipe is placed inside another, with tight-fitting sleeve joints. The jacket-pipe has its ends separated by a distance of 12 inches to permit the inner pipe to be screwed home. The 12-inch gap is afterwards covered by a sleeve and the space is filled in with molten lead. The line is held in place in the river bed by two sets of heavy chains lying parallel with the pipe on either side about 25 feet from it. Guide chains connect the pipe with the main chains, and an anchor weighing a ton, and connected to each guide chain, keeps the whole in place. The line crossing the salt marshes near the river is laid in a wooden casing lined with hydraulic cement to prevent corrosion.

Only a rough estimate of the length of the 2-inch branch lines, which belong to the various well owners, can be arrived at. A representative of the Standard Oil Company, appearing before a committee of the State Legislature, in February, 1891, stated that the total length of lines transporting Pennsylvanian crude oil was undoubtedly 25,000 miles. The trunk pipe-lines are made up in 18-foot lengths of specially made and tested lap-welded wrought-iron pipe known as "oil-line pipe." The lengths are connected by long sleeve couplings cut, as are the ends of the pipes, with coarse and sharp taper threads, nine to the inch, the taper being usually three-quarter inch to the foot, for 4-inch pipe. The lines are usually laid two or three feet below the surface of the ground, and are provided at intervals with bends, to allow for expansion and contraction under changes of temperature.

The section of line between each pair of stations is in charge of a "linesman," who walks along the line to look for small leakages, &c. To remove obstructions in the pipes caused by the separation of solid paraffin, or collection of sediment, an automatic rotary scraper is forced through with, and at the same speed as, the oil (about three miles per hour). The instrument makes sufficient noise to be heard outside, and was formerly followed by workmen, who could thus locate an obstruction; but this is no longer thought necessary. The scraper is known as a "go-devil," and has been made in various forms. That now in use has a ball and socket joint at the centre to permit of its passing the bends of the pipe. The spindle is fitted with radial steel blades, which scrape the pipe, and with oblique vanes, which cause it to rotate as it advances. The "go-devil" is provided at both ends with three arms, each terminating in wheels, which serve to keep it in the proper position in the pipe. The apparatus falls into a catch-box at the end of the pipe, on the completion of its journey.

Pumping Oil through Pipe-Lines.—Mr. J. H. Harris has given some interesting particulars[1] of the development of the pipe-line system of transportation in the United States, particularly as regards the pumping plant employed. The oil was formerly forced through the pipes by single-cylinder or "donkey" pumps, the steam cylinders of which were in some cases of a diameter of 30 inches, the ram being only 4 or 5 inches. Owing to the excessive strain and jar produced at each stroke, the pipes were found to constantly require repair, and the expense thus entailed was prohibitive. The type of pump now in use was introduced for the purpose by Mr. Henry R. Worthington, and first put into operation near Bradford, on the Erie Railway. "The result of the working of this machine was to revolutionise the entire transportation of petroleum. It exceeded even the maker's anticipations. The action of this pumping engine under these severe conditions was as quiet and as free from harshness of motion as could be desired. The movement of the column of oil through the pipe was uniform and constant, and whereas, under the old system of single-cylinder pumps, the column of oil came to a stop at the end of each stroke, with a variation of pressure on the gauge of several hundred pounds, with the Worthington type there was no stoppage, but a constant flow from the starting to the stopping of the engine, and an almost uniform pressure on the gauge. From 1878 to 1882, the building of trunk lines to the seaboard was continuous, and refining of oil in the oil-regions proper, either remained stationary, or, as the different refineries were destroyed by fire (a fate which overtakes them all sooner or later), refining was discontinued, while on the seaboard and lakes, large and extensive refineries were erected."

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[1] *British Association Report*, 1885.

On the New York line there are eleven pumping stations, each comprising a boiler-house, a pump-house, a telegraph office, and two or more tanks. The station is provided with two pumps, each having twenty-eight suction and twenty-eight supply valves. The pump has a double-stroke action, and moves forward a barrel of oil at each stroke, every seven seconds, both day and night. The pumps are worked by compound condensing engines, and are provided with pressure-gauges and with indicators which register the quantity of oil pumped. In 1885, the average amount pumped through the New York line was about 28,000 barrels daily, the average "head" due to friction and elevation of the pipe-line being about 900 lbs., sometimes rising to 1,200 or 1,500 lbs. (*i.e.*, a head of from 2,175 to 3,450 feet), according to the piston-speed of the pump.

The engines on the main 6-inch lines are from 600 to 800 H.P.; those on the 4-inch and 5-inch lines being from 150 to 200 H.P., and on the local lines from 25 to 30 H.P. Each pump has two steam-jacketed high-pressure and two low-pressure cylinders, each set working tandem and direct-acting. Each pair of cylinders actuates two single-stroke rams packed externally, and in passing from the high-pressure to the low-pressure cylinder, the steam traverses a receiver, in which it becomes heated. The valve boxes are divided into small chambers, with leather-lined metal valves having a small lift, but large surface. The following are the dimensions of a pump of 440 horse-power:—

	Inches.
Diameter of low-pressure steam cylinder, ...	66
Diameter of high-pressure steam cylinder, ...	33
Diameter of plungers, ...	9¼
Stroke, ...	37¾

Average duty, 105,000,000 foot-pounds per 100 lbs. of coal.

Rated capacity, 1,500,000 gallons against a pressure equal to 2,000 feet head of water.

A pair of compensating cylinders and plungers at the outer end of the rams maintain an even pressure along the line. The cylinders are each mounted vertically on trunnions, and a heavy pressure from an accumulator tends to thrust the plungers outwards. As the main-pump rams move outwards, the cylinders swing on their trunnions into an increasingly oblique position, while their rams are forced outwards and reinforce the action of the steam, the pressure of which is diminishing from expansion. On the return stroke, the cylinders return to the vertical position, and their rams are forced back by the high-pressure steam, against the accumulator pressure. Thus, the power of the outer and inner strokes of the pump is nearly equalised, and the oil in the pipe-line is kept in constant and regular motion, the concussion resulting from an intermittent flow being obviated.

The National Transit Company are now using large triple-expansion fly-wheel engines for the trunk line service. At each station, there is generally one such engine and a low-duty engine for relief work. In each station having a high-service pump, there are seven or eight horizontal tubular boilers of 80 to 100 H.P. each. They are placed in a brick house 40 feet square, with a roof of corrugated iron, and six are fired at a time. On the Tide-Water line, the pumping stations are placed at distances apart varying with the incline.

Storage of Crude Petroleum.—The oil is received at each station in one or more tanks made of boiler-plate, and from these it is pumped to similar tanks at the next station. In some cases, loops have been laid round stations, and oil has been thus pumped direct through a length of 110 miles.

The oil received from the individual wells is measured by the owner and the pipe-line company's officer, and the owner is credited with the amount in the company's books. By this system, of course, all the oil goes into the common stock, so that no producer can afterwards obtain his own oil, but only an equivalent quantity from the stock tanks. Specially heavy oils, such as that of the Franklin district and of Smith's Ferry, are therefore transported in barrels.

The tanks used at the wells are usually circular and of wood. They commonly hold about 250 barrels, but are sometimes of two or three times that capacity. As soon as the well is found to yield, the tank is connected by a 2-inch pipe with the trunk line. Three per cent. of the oil is deducted for "shrinkage" or loss during transport, an agreed proportion is credited to the landowner, and the remainder is credited in the company's books to the producer. The oil may be transferred to a purchaser by a written order or "certificate," which is negotiable similarly to a cheque. The Oil Exchanges deal only in certificates for 1,000 barrels, but smaller quantities are saleable. Any oil destroyed by fire is deducted *pro rata* from the total stock. The company allows thirty days' free storage, but afterwards makes a charge per barrel per month until the oil is withdrawn. Large storage tanks at convenient stations are owned by the National Transit Company. They are usually made 90 feet in diameter by 30 feet in height, and have slightly conical wooden roofs covered with sheet-iron. Their capacity is 35,000 barrels. They are placed upon the carefully-levelled ground without any foundation. Professor Peckham quotes the following specification, used by the United Lines in making contracts, as giving a good idea of the construction of these tanks:—

UNITED PIPE LINES SPECIFICATION FOR A 35,000 BARREL TANK.

Dimensions.—Tank to be 90 feet in diameter and 30 feet high, and to be composed of seven rings.

Sheets.—The first ring to be of No. 00 (Birmingham gauge), weighing 13·64 lbs. per square foot. The second ring to be of No. 0 (Birmingham gauge), weighing

12·04 lbs. per square foot. The third ring to be of No. 1 (Birmingham gauge), weighing 11·40 lbs. per square foot. The fourth ring to be of No. 2 (Birmingham gauge), weighing 10·40 lbs. per square foot. The fifth ring to be of No. 3 (Birmingham gauge), weighing 9·55 lbs. per square foot. The sixth ring to be of No. 4 (Birmingham gauge), weighing 8·83 lbs. per square foot. The seventh ring to be of No. 6 (Birmingham gauge), weighing 8·15 lbs. per square foot. The bottom to be of No. 6 (Birmingham gauge), with five sketch plates, weighing 8·15 lbs. per square foot.

Angle-iron.—The bottom angle-iron to be 4 by 4 by ½ in. The top angle-iron to be 2 by 2 by ⅜ in.

Rivets.—The bottom angle-iron and first ring to be riveted with ⅝-inch rivets; the second and third rings with ½-inch rivets driven hot; and the remaining rings with ⅜-inch rivets driven cold. The vertical seams of the first, second, third, and fourth rings to be double-riveted.

Roof.—The roof to be conical, with a rise of at least 5 feet 6 inches to the centre (1·2 inch to the foot), and to be covered with No. 20 iron, painted on both sides and riveted to the top angle-iron. The ends of the rafters supporting the roof must not rest on the angle-iron, but upon posts placed next to the shell of the tank inside.

Manhole.—The manhole to be of wrought-iron throughout, and 20 inches in diameter, and be placed 10 inches from the bottom of the first ring, in the sheet adjoining that in which the outlet-valve is placed.

Hatches.—There shall be two hatches in the roof, each 2½ by 3 feet, provided with suitable covers. One of the hatches shall be directly over the outlet-valve, the position of the other to be determined by the superintendent of the United Pipe Lines.

Swing-pipes.—There shall be two swing-pipes. one of 6¼-inch casing for oil, and one of 1½-inch pipe for water; each pipe to be 30 feet long and to have 50 feet of chain fastened to it by clamps, the chain for the 6¼-inch pipe to be $\frac{5}{16}$ inch, and the chain for the 1½-inch pipe to be ¼ inch.

Flanges.—The flange for the pipes to be of wrought-iron, and securely riveted to the tank; the flange for the 6¼-inch pipe to be at least 1¼ inch thick where the thread is cut.

Valves and Connections.—The oil-valve to be a 6-inch iron body, brass-mounted, flanged gate-valve. The connections for the oil swing-pipe to consist of one 6-inch nipple (eight threads to inch), with 10 inches of thread on one end and ordinary thread on other end. One 6-inch elbow (eight threads to inch) on one end, and 6¼-inch casing thread on other end. One 6-inch nipple, 18 inches long, ordinary threads both ends (eight threads to inch). The water-valve to be a 1½-inch iron-body screwed gate-valve. The water connections to be one 1½-inch nipple with 6 inches of thread on one end and ordinary thread on the other. One 1½-inch nipple, 6 inches long, with ordinary thread both ends. Two 1½-inch elbows.

Windlass.—There shall be a windlass over one of the hatches to raise the swing-pipes.

Stairs.—The stairs to be substantially constructed, and furnished with a gate. The tank to be carefully painted with red paint, and to be completed in every part in a thorough and workmanlike manner.

Specifications under which the storage tanks of many of the pipe-lines are built are given in the table on p. 477.

Transport by Rail.—The tank-cars now employed in the United States for railway transport, are constructed with horizontal cylindrical boiler-plate tanks, furnished with a dome similar to that of a steam boiler. Fig. 167 shows a number of these cars at a railway siding, together with the arrangements employed for simultaneously charging a train of them. An orifice is provided in the top of the dome for filling, and a valve at the bottom of the tank for discharging. The

TABLE LV.—SPECIFICATIONS OF STORAGE TANKS.

Capacity (Barrels of 42 American Gallons each) about.	1,000.	2,000.	3,000.	4,000.	5,000.	10,000.	15,000.	20,000.	25,000.	30,000.	35,000.
Diameter of tank, in feet, . . .	30	30	30	35	43	54	66	78	86	86	92
Height of tank, in feet, . . .	8	16	24	24	20	25	25	25	25	30	30
Number of rings in shell, . . .	2	4	5	5	4	6	6	6	6	7	7
Thickness of first ring (Birmingham gauge), .	No. 7	No. 5	No. 3	No. 3	No. 3	No. 3	No. 3	No. 2	No. 1	No. 0	No. 00
Thickness of second ring, .	No. 8	No. 6	No. 4	No. 4	No 4	No. 3	No. 3	No. 3	No. 2	No. 1	No. 0
Thickness of third ring, . .	...	No. 7	No. 5	No. 5	No. 5	No. 4	No. 4	No. 4	No. 3	No. 2	No. 1
Thickness of fourth ring. .	...	No. 8	No. 6	No. 6	No. 6	No. 5	No. 5	No. 5	No. 4	No. 3	No. 2
Thickness of fifth ring, . .	...	...	No. 7	No. 7	...	No. 6	No. 6	No. 6	No. 5	No. 4	No. 3
Thickness of sixth ring, . .	...	...	...	...	...	No. 7	No. 7	No. 7	No. 6	No. 5	No. 4
Thickness of seventh ring, .	...	...	...	...	...	...	...	...	...	No. 6	No. 6
Thickness of bottom plates,	No. 7	No. 7	No. 7	No. 7	No. 7	No. 7	No. 6	No. 6	No. 6	No. 6	No. 6
Thickness of sketch plates, .	No. 7	No. 7	No. 7	No. 7	No. 7	No. 7	No. 6	No. 6	No. 6	No. 6	No. 5
Size of bottom angle iron, in inches, . . .	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	$3 \times 3 \times \frac{3}{8}$	$3 \times 3 \times \frac{3}{8}$	$3 \times 3 \times \frac{3}{8}$	$4 \times 4 \times \frac{1}{2}$	$4 \times 4 \times \frac{1}{2}$
Size of top angle iron, in inches,	$2 \times 2 \times \frac{1}{4}$	$2 \times 2 \times \frac{1}{4}$	$2 \times 2 \times \frac{1}{4}$	$2 \times 2 \times \frac{1}{4}$	$2 \times 2 \times \frac{1}{4}$	$2 \times 2 \times \frac{1}{4}$	$2 \times 2 \times \frac{1}{4}$	$2 \times 2 \times \frac{1}{4}$	$2 \times 2 \times \frac{1}{4}$	$2 \times 2 \times \frac{1}{4}$	$2 \times 2 \times \frac{3}{8}$
Thickness of sheets for light nailed roof, .	No. 20	No. 20	No. 20	No. 20	No. 20	No. 20	No. 20	No. 20	No. 20	No. 20	No. 20
Thickness of sheets for tight riveted roof, .	No. 12	No. 12	No. 12	No. 12	No. 12	No. 12	No. 12	No. 12	No. 12	No. 12	No. 12

usual size of the tanks was formerly about 24 feet 6 inches in length, and 5 feet 6 inches in diameter, and the capacity from 4,500 to 5,000 gallons (American); but tanks about 32 feet in length and 6 feet in diameter, holding 8,000 gallons (American) are now employed. The ends of the tank are slightly convex, and are of $\frac{5}{16}$-inch plate, the bottom being of quarter and the upper part of $\frac{3}{16}$-inch plate. The tank is fastened to the truck by iron bands, to prevent movement from vibration or from sudden stoppage of the train. The total number of tank railway cars in use in the United States is between nine and ten thousand. Fig. 168 shows the form of loading rack employed for charging all the tanks in a train simultaneously. A raised platform extends along the side of the railway for a distance equal to the maximum length of the tank train, and at about the height of the tops of the tanks. The rear uprights of the framework on which the platform is laid, extend upwards, and are recessed at the top to form supports for the filling-pipes, which are 6 inches in diameter, and are provided with T branches at intervals equal to the

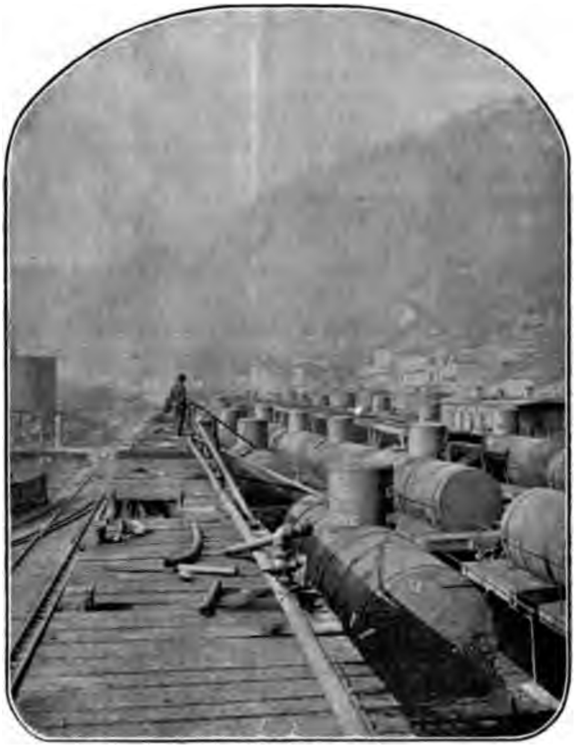

Fig. 167 (from a photograph.)

distance between the domes of two tanks cars. Each T piece is fitted with a short length of upright pipe, furnished with a tap, and with a sleeve or draw-pipe for placing in the opening in the tank-dome. By means of such a rack, one man can charge a whole train in about half an hour.

Transport and Distribution of Kerosene.—In the United States, the distribution of kerosene is principally effected by means of tank barges, tank railway cars (already described), and tank road wagons, but wooden barrels, steel or iron drums, and tin cases of various sizes are also employed. Some of the tank barges are as much as 125 feet in length by 30 feet beam, and carry half a million gallons of oil. Such barges are built of steel, and are divided into three oil compartments, a small space being left at the stem and stern to give the necessary buoyancy.[1] The tank road wagons are fitted with horizontal cylindrical steel tanks, which are in some cases about 8 feet in length and 3½ feet in diameter; but the dimensions vary according to circumstances, the large sizes being used in cities having paved level streets,

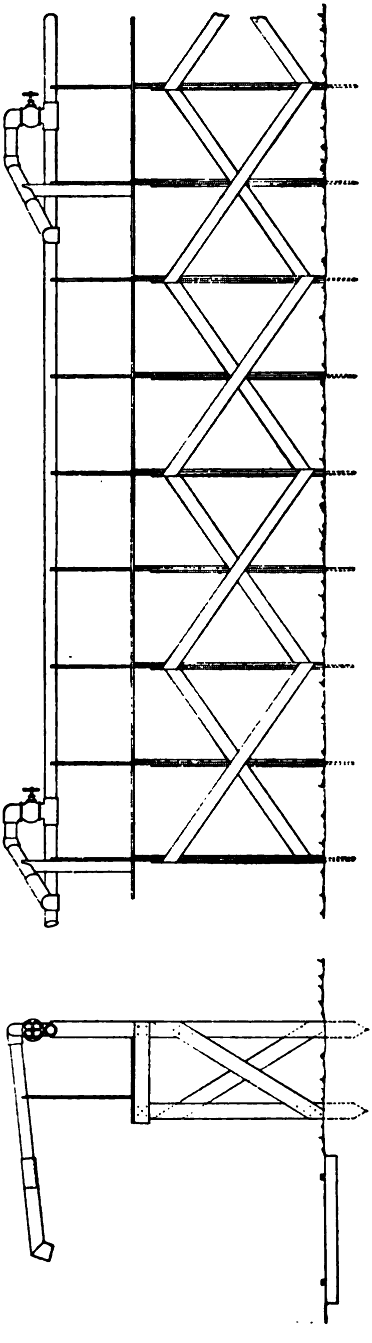

Fig. 168.

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[1] It is reported that an attempt is to be made to introduce the system of towing barge loads of kerosene in bulk across the Atlantic, and that the first experiment will shortly be made with a tank barge carrying 3,000 tons of oil. The steam towing appliance of Shaw & Speigle, whereby the strain on the hawser is equalised by the interposition of what is in effect a steam cushion, will be adopted. With this arrangement a steel hawser can be safely employed, and it is expected that, under such circumstances, the towing will be successfully effected.

the smaller sizes in the hilly outlying districts, or in sections where the trade is limited. The capacity, therefore, ranges from 250 to 1,000 gallons (American). As already stated, the organisation known as the United States Pipe Line transports refined oil by one of its lines, the oil being thus conveyed from Reno, Oil City, Titusville, Warren, and Bradford, to Wilkesbarre, Pa.; but, with this exception, pipe-lines are not employed for the distribution of kerosene.

For shipment from the United States by sea, part of the kerosene is barrelled, or put into cases, but a very large proportion is now transported in bulk in specially constructed tank steamers, which will be hereafter described. Crude petroleum is also shipped in bulk in tank steamers, and to a small extent in bulk sailing vessels, some, however, being still exported in barrels. Lubricating oils are invariably transported in barrels, and this method of carriage is also adopted for naphtha and gasoline, though recently the shipment of naphtha in bulk by tank steamer, has been adopted.

According to the rules of the New York Produce Exchange, petroleum barrels should be made of well-seasoned white oak, and should be bound either by six or eight iron hoops. When six hoops are used, the head hoop should be 1¾ inch wide, No. 16 gauge (English standard); the quarter hoop 1½ inch wide, No. 17 gauge; and the bilge hoop 1¾ inch wide, No. 16 gauge. When eight are used, the head hoop should be 1¾ inch wide, No. 17 gauge; the collar hoop 1¼ inch wide, No. 17 gauge; the quarter hoop 1½ inch wide, No. 18 gauge; and the bilge hoop No. 18 gauge. All old barrels, the gross (full) weight of which is less than 395 lbs., may be hooped by six hoops 1½ inch wide, excepting the chime hoop, which should be 1¾ inch wide. Barrels are divided into three classes—(1) capable of carrying refined petroleum or naphtha; (2) unfit for such purpose, but suitable for carrying crude petroleum; and (3) suitable only for residuum.

The barrels employed in the shipment of kerosene from the United States are chiefly made by machinery, the Standard Oil Company being able to turn out from their cooperage at Bayonne, from 10,000 to 12,000 finished barrels daily.

The following description of the manufacture of petroleum barrels in the United States is extracted from the Cantor Lectures delivered by the author before the Society of Arts in 1886:—

"The oak staves are purchased ready jointed and seasoned in Michigan, and the barrel heads are brought to the works ready glued up. The first operation in barrel making consists in fitting the necessary number of staves together in a thick wrought-iron ring encircling their lower ends. This is an operation requiring some experience and judgment. The embryo barrel is then placed in an iron cylinder and steamed, whereby the wood is softened. The staves are next encircled by a wire rope connected with an engine, and are thus bent into shape and drawn together, a second strong iron hoop being slipped on their upper ends to hold them in position. The barrel is then 'fired' by burning some readily combustible material in the interior, and the curvature of the staves thus rendered permanent. A number of extra temporary iron hoops of great thickness are next slipped on, and drawn toward the bulge of the barrel by means of an ingenious arrangement of iron hooks or claws actuated by steam power. The final operation performed upon the staves consists in placing the barrel in a lathe, paring off the rough ends, and cutting the grooves for the heads.

"The barrel is then ready to receive the heads and to be hooped. The hoops weigh collectively about 12 lbs., and the total length of iron required for a set, is 443½ inches, so that putting the out-turn of finished barrels from one factory at 10,000 per day, we have a length of about 70 miles of hoop iron (weighing about 55½ tons) used daily.

"In order to render the barrels capable of holding their fluid contents without leakage, they are coated internally with glue, about one pound of glue to three barrels being required. The glue solution is poured into the barrels hot, the barrels bunged up, and rotated so that the solution coats the entire surface, the surplus being afterwards drained out. There is some pressure of steam in the barrel during the operation, and a leak is thus at once shown. The barrels finally receive a coating of the well known blue paint on the staves, and white paint on the heads. Oil barrels returned to be refilled are often cleaned externally by an arrangement of rapidly revolving wire brushes, are steamed out, reglued and repainted.

"Before the barrels are filled, the hoops require 'driving' to take up the shrinkage of the wood. This was formerly done exclusively by hand, but Mr. Hopper has invented a successful machine for doing this by steam power. In this apparatus, the barrel stands on a platform arranged like an inverted steam hammer, and on turning on the steam, it is brought, with a succession of blows, against a number of hinged stops, which closely encircle the barrel and on which the hoops strike. With one such machine, the hoops of 2,000 barrels can be driven in ten hours by one man and two boys—an amount of work which formerly entailed the hand labour of ten men."[1]

The arrangements adopted in filling the barrels are described at the end of this section, but it may here be mentioned that the exit pipes from the filling rack are provided with automatic valves which stop the flow of oil when the barrel has been filled to within a gallon of its contents. The shives with which the barrels are closed are of wood, and are put in with glue. A package which remains perfectly tight and free from leakage as long as it is handled carefully, so that the continuous skin of glue remains intact, is thus produced.

The tins already mentioned as being used for the carriage of kerosene, are also made by machinery, the plates being cut, stamped, bent, and soldered by a series of distinct machines. The wooden cases, each of which contains two of the tins, are put together by nailing machines which drive in the whole of the nails for each angle at one operation. At the Devoe works in New York, 60,000 tins and 30,000 cases are made daily. It is stated that 40,000 tons of tin plate was used in America in 1887 for the manufacture of kerosene tins. The cans each hold 5 American gallons (slightly over 4 imperial gallons). The outside dimensions of the wooden case are 20¾ inches long by 15 inches high, by 10¼ inches wide, and the total weight when the cans are full of oil, is about 80 lbs. The can is hermetically sealed for transport, but is provided with a screw cap for subsequent use, and is fitted with a wire handle.

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[1] A paper, by Mr. R. H. Ransome, on the manufacture of wooden barrels by machinery, will be found in the *Minutes of Proceedings of the Institution of Civil Engineers*, cxv. (1893), 193-204.

The case forms a very convenient package for the distribution of the oil in comparatively inaccessible districts, where primitive means of conveyance are necessarily employed, and in Eastern countries in particular, the empty tins are of value, as they are converted into various domestic utensils, such as cooking vessels and lamps.

CANADA.

In Canada, pipe-lines are also employed, but the system has not been fully developed as it has been in the United States, and the well-owner therefore frequently conveys his oil by road to the nearest receiving station. For this purpose, a long, slightly-conical wooden tank or barrel, resting on its side on a wagon, is employed. The tank has a capacity of from eight to ten barrels.

The storage tanks commonly employed in Canada, are merely excavations made in the impervious soft clay (the "Erie" clay) occurring in the oil district. In making a large tank, a cylindrical excavation 60 feet in depth and rather over 30 feet in diameter is made, the 18 or 20 feet of alluvium above the clay being curbed with wood and well puddled with clay. While the excavation is in progress, the walls are protected by vertical planks supported by horizontal wooden rings. The actual wall or lining of the tank is then constructed of planks nailed together, the planks which before supported the sides of the excavation being removed, and the space filled in with clay carefully rammed in. The bottom of the tank is not treated in any way. The roof is formed of planks, and is rendered watertight by a layer of clay. An 8,000 barrel tank of this description can be completed in six weeks at a cost of $1,760.

Sec. 20 of the Mercantile Amendment Act of Ontario, 1887, includes Statute 25 of 1885, which legalised the transfer by endorsement of certificates of stored crude petroleum, and provides that storage companies must include in their returns particulars of the total quantities of crude petroleum actually held by them for the purpose of answering such warrants, and the total quantity of which they are bound to make delivery, as warehousemen and carriers, to other persons.

RUSSIA.

The transport of crude petroleum in Russia by means of the Persian "arbas" has already been referred to. This method has long since been superseded by the employment of pipe-lines. The first pipe-line from the wells to the refineries at Black Town (see Fig. 169, which is taken from a paper by Marvin in *Engineering*, March 21, 1884) was laid by Nobel Brothers in 1879, and it was found necessary to erect throughout its length of eight or nine miles a series of watch-houses occupied by armed men, to prevent wilful injury to the pipes by the owners of the arbas. In 1884, there were seven pipe-lines, but the number has since been increased to twenty-two, some of the lines having a diameter of as much as 8 inches.

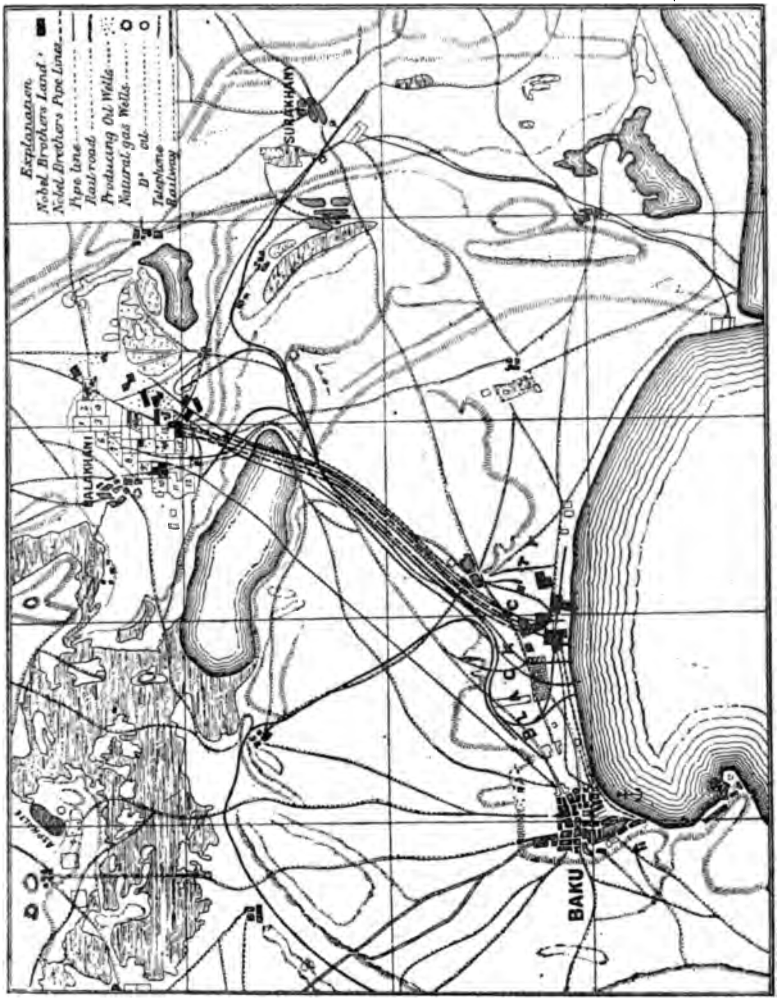

Fig. 169.—Map of Baku District, showing Pipe Lines.

The oil is stored at the wells in iron tanks usually from 50 to 60 feet in diameter, and from 30 to 40 feet in height. From these tanks the oil is conducted to the pumping stations. There are several companies which undertake the transport of the oil to the refineries at a cost of about ¼ copeck per pood.

Nobels were also the pioneers of bulk transport by sea, and in 1881 introduced the use of tank cars on the Russian railways. Of these cars there is now a very large number in use on the Trans-Caucasian and other railways. The tank cars resemble those used in America, and hold about 10 tons (2,700 gallons) of kerosene. A whole train of twenty-five cars can be charged in about an hour. Many of the cars formerly belonging to the refiners, have been acquired by the State Railways by payment of 1,800 roubles per car, subject to a deduction of 250 roubles for each year of previous service. A car usually lasts from eight to ten years.

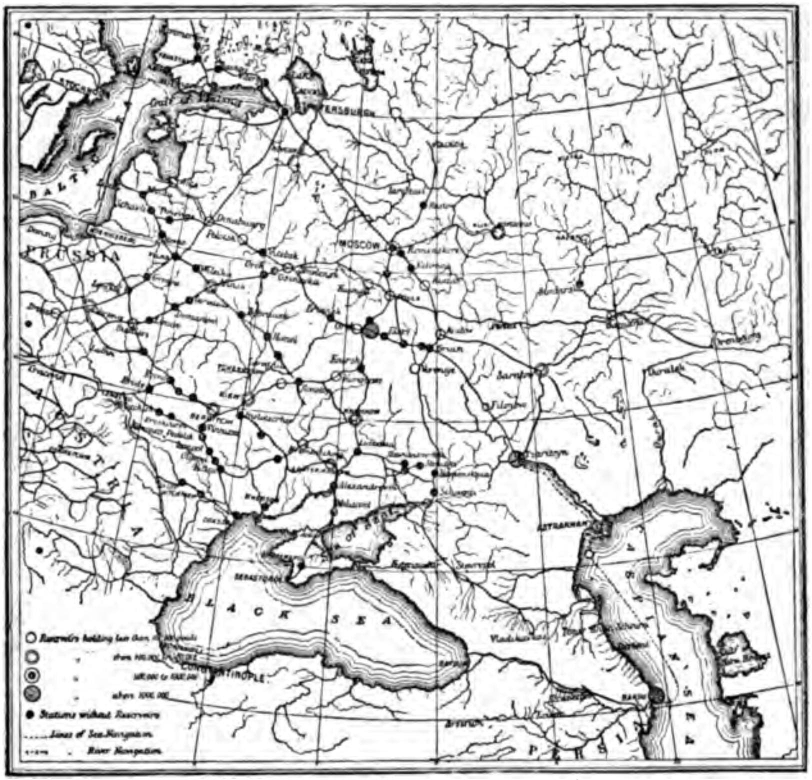

Fig. 170.—Map showing the Nobel System of Storage.

Fig. 170 shows the system adopted by Messrs. Nobel for the storage and distribution of kerosene in Russia. As the Volga is frozen during four months in the winter, and but little oil is used during the summer when the boats can run, a number of large storage reservoirs were erected in convenient distributing centres. The largest depôt is at Domnino, near Orel, in Central Russia, and there are other important ones at Moscow, St. Petersburg, Warsaw, and Saratoff. The Orel reservoirs are thirty-two in number, and are collectively capable of holding 18,000,000 gallons of kerosene. During the summer, the oil is carried by tank trains to the various storage depôts, and during the winter, it is similarly distributed throughout the country. The kerosene is conveyed by tank steamers from the refineries to the mouth of the Volga, where it is transferred to tank barges which carry it to Tsaritzin, 284 miles above Astrakhan. At Tsaritzin, where there is a large storage station, the oil is transferred to the tank cars on the railway. In the office of Nobel Brothers at St. Petersburg, large-scale maps are kept, on which (somewhat as in the case of the ships on the Suez Canal) the positions of the trains, as their arrival at each station is telegraphed, are marked by flags.

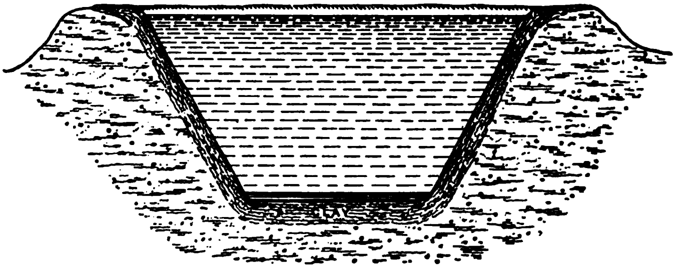

Fig. 171.

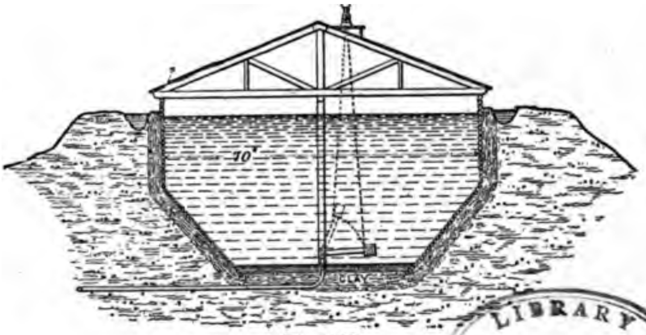

Fig. 172.

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Writing in *Engineering* in 1884, Mr. Marvin states that, although the Brothers Nobel came fresh to the petroleum trade in 1875, they had in 1884, twelve large cistern steamers for marine transport, and twelve steamers and forty barges for the traffic on the Volga, in addition to a large number of chartered schooners and barges and the tank cars already mentioned.

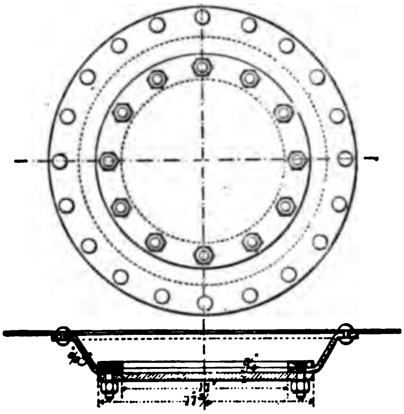

Fig. 173.

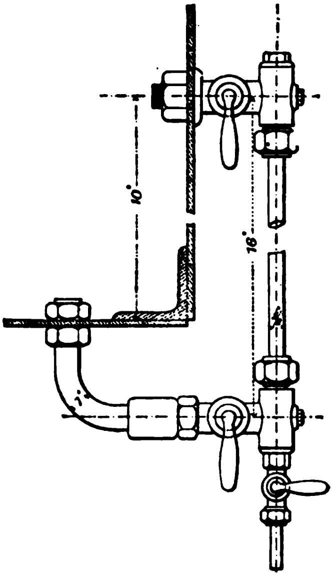

Fig. 174.

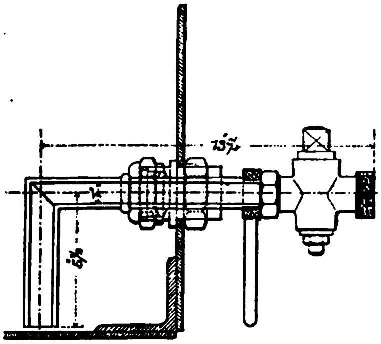

Fig. 175.

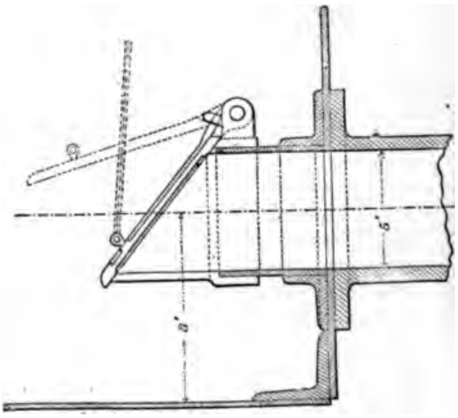

Fig. 176.

Storage.—Mr. T. Urquhart describes[1] the construction of tanks and reservoirs for crude petroleum, kerosene, and astatki in Russia.

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[1] *Min. of Proc. Inst. Civ. Engineers*, 1891, cv., 139.

The tanks are made of boiler plate, and resemble those described as in use in America. Figs. 171 and 172 represent two excavated reservoirs lined with clay and wood, one of them being surrounded by a water moat. The roof of such a reservoir is usually made of sheet iron laid upon a light wooden scantling. The capacity of the reservoir shown in Fig. 172 is 5,650 tons of astatki, its dimensions being 70 feet in width and 112 feet in length.

All the iron tanks built at Tsaritzin, and on the Grazi-Tsaritzin Railway, are simply set upon a bed of sand about 6 inches in thickness on the levelled ground. The manhole fittings were formerly of cast iron, but as these were found to be liable to crack, they have been replaced, at Mr. Urquhart's suggestion, by the wrought iron fittings shown in Fig. 173. The new fittings are stamped out of half-inch boiler plate, and are provided with covers of wrought iron.

Fig. 174 represents a glass gauge fitted to the tank to show the amount of water which has accumulated, and Fig. 175 represents the form of water extractor used. Both these appliances are enclosed in locked boxes, and the depth of water is usually noted once a week. A clack valve (Fig. 176) is in some cases placed on the end of the delivery pipe inside the tank as a precautionary measure. It is opened by a chain running over a pulley fixed to the upper edge of the tank, and is normally kept closed by the weight of the petroleum.

Transport of Kerosene. — The export of kerosene to other countries is principally conducted from Batoum, where the oil is either shipped in bulk or in cases, such as have long been employed for the shipment of American petroleum. Owing to the expense and difficulty of railway transport from Baku to Batoum, a distance of 560 miles, it has been proposed to transport the *crude* oil by a pipe-line to the latter port, or to Poti, where it would be refined.

Mr. G. Stockfleth, C.E., who was formerly connected with the Russian petroleum industry, has recently furnished the author with the following particulars relating to the transport of petroleum products from Baku. The kerosene and other products are transported by sea to various ports on the Caspian, but principally to Astrakhan. From this port, the kerosene is conveyed by river to Tsaritzin, whence it is distributed by rail for home consumption, or may be carried over the frontier to Austria and Germany. A certain quantity goes also to Scandinavia, *via* Libau and Riga. Nearly the whole of that which is intended for export is, however, conveyed by rail to Batoum, and is thence shipped to European and Oriental ports.

Until the Baku-Batoum railway was built, Russian petroleum was exclusively transported *via* Astrakhan, and as the quantity only amounted to one-twentieth of the present production, it was all needed for home consumption, and was conveyed in barrels. The late Mr. Ludwig Nobel of St. Petersburg, founded, in 1878, the firm of Nobel Brothers, and introduced transport in bulk by sea and rail. After considerable difficulty with the railway companies, the first 200 tank cars, built on the American system, were put in service by Nobel Brothers, and in 1881, the first petroleum train, of twenty-five cars, arrived at St. Petersburg from Tsaritzin. The number of cars was rapidly increased, and in 1889, the Company owned nearly 2,000.

Meanwhile, the Baku industry had grown with great rapidity, a number of refineries had been established, and the Baku-Batoum railway had been opened, but as this line had been built with a single track, and with many steep gradients, particularly one over the Suram Pass, where only six cars could be hauled at a time, and those only at a low rate of speed, the carrying capacity was not equal to the requirements. Moreover, the Baku refineries had to provide tank cars, and above all, water was so scarce at the stations that the locomotives were sometimes kept waiting for days before obtaining a supply. Nobel Brothers then obtained a concession for the construction of a 4-inch pipe-line about 60 miles in length, over the Suram Pass, with a tank installation at each end, and this largely facilitated the transport.

Great improvements have, however, been effected by the railway company. Additional stations with sidings have been constructed, a tunnel has been made at the Suram Pass, and tank cars are now provided by the company. At the present time, the transport is properly conducted, and is equal to the demand. The railway rate for the carriage of petroleum from Baku to Batoum is 9 copecks the pood at the present time, but until recently was 19 copecks, and on that basis resulted in a yearly profit of 4,000,000 roubles.[1]

The transport by sea from Baku is effected by tank steamers and sailing vessels, the latter carrying kerosene in barrels or astatki in bulk. There is a fleet of about a hundred wooden sailing ships, of from 20 to 50 tons capacity, in which the residuum is carried in bulk in the hold. Owing to the cheapness of the cargo, these primitive tank ships, with their unavoidable defects and sources of loss, answer their purpose very well. Of the tank steamers, the first two were designed in 1878 by Mr. Ludwig Nobel in conjunction with Mr. Sven Almquist, manager of the Motala shipbuilding works in Sweden. Tank ships were then a novelty, and there was the further difficulty that no suitable works for building them existed at Baku or Astrakhan. The vessels were accordingly constructed at Motala, and as they had to be conveyed to the Caspian Sea through the narrow and shallow waterway uniting the Neva with the Volga, they were built in sections, and after making the voyage from Sweden to St. Petersburg and up Lake Ladoga, were divided into three, four, or five cross sections, each of which with its watertight bulkheads, separately passed through the canals and locks of the interior of Russia, supported by special pontoons on account of the shallowness of the water. This was necessarily a slow and difficult operation, and as it unfortunately happened that frost and a period of low water occurred before the sections had reached the navigable part of the Volga further progress was stopped for eight months. When sufficiently deep water was reached, the sections were put together with bolts and rivets and the vessels then proceeded to Baku to commence the service, in which they are still engaged without having shown any defect. The success which attended this experiment, soon led to the general use of tank steamers for the shipment of kerosene in bulk from Baku.

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[1] According to a recent report by Her Majesty's Consul at Batoum, the Russian Government contemplate again adopting the former rate of freight at an early date.

The oil carried by the Trans-Caucasian railway is stored at Batoum before being shipped by tank steamers or in cases for transport to European and Asiatic ports. Batoum has through the petroleum industry become an important town, although its development as a port of shipment for kerosene has been somewhat retarded by its being a Russian strategic position, restrictions having in consequence been placed upon the erection of storage tanks. The more important refiners have, however, their tank installations with pipe-lines conveying the kerosene to a well-built stone pier where steamers can load in safety, there being about 28 feet of water. As railway transport is now more expeditious than formerly, the existing storage capacity is at present sufficient for the requirements of the trade. Before the new pier was built, it was often difficult to load tank steamers at Batoum, as in bad weather the vessels could not approach the wooden piers, and considerable delay often occurred before connection could be made with the pipe-line on shore. The steamers had to load at the stern and were fitted with a pipe (the "Batoum pipe") for this purpose, but at present they can load amidships.

Large quantities of oil are shipped in cases containing two tin cans, each of 4 gallons capacity, to Asia *via* the Suez Canal, and there are at Batoum several case factories, of which the one belonging to Messrs. Rothschild is the most important.

TANK STEAMERS.

The marine transport of petroleum in tank steamers has been very fully discussed by Mr. Benjamin Martell,[1] Mr. George Eldridge,[2] Mr. J. Fortescue Flannery,[3] and others; and numerous descriptions of recent tank ships have appeared in *Engineering*, *The Engineer*, *Industries*, and other technical journals. The subject has also been dealt with by Mr. G. H. Little.[4]

In his first paper on the subject, Mr. Martell points out that, at the time of writing (1886), nearly the whole of the petroleum shipped from America was contained in barrels or in cases. The weight of an ordinary barrel of 42 gallons capacity is 64 lbs.—about one-fifth of the weight of the oil it contains. The net weight of oil in barrels which a ship capable of carrying 2,000 tons of deadweight cargo can contain is about 1,030 tons, after allowing for the weight of the barrels and loss by leakage, &c. The barrels were said to cost from 4s. 6d. to 5s. 6d. each in the United States, and as they were usually sold after arrival in London for 3s. 6d. to 4s. each, there was a loss of from £350 to £475 on the cargo above mentioned.

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[1] *Trans. Inst. Naval Architects*, July 27, 1886, and July 11, 1893; *The Marine Architect*, Sept. 1, 1886, viii., 183; and *Engineering*, July 14 and 21, 1893.

[2] *Trans. Inst. Naval Architects*, July 24, 1891.

[3] *Proc. Internat. Maritime Congress*, London Meeting, 1893; *Shipping Gazette and Lloyd's List*, July 22, 1893.

[4] *The Marine Transport of Petroleum*, 1890.

As regards the cases, Mr. Martell remarks that the tin is shipped from Wales to the United States, and is there made up at a cost nearly equal to that of the contents.

In a work of this character, details of the construction of tank steamers would be out of place, and for these, reference should be made to the publications already mentioned. The following description of the main principles upon which such vessels are designed may, however, be of interest.

Mr. Martell enumerates as essential features of construction:—

1st. Provision for the expansion of the oil under an increase of temperature.

2nd. Provision for keeping each tank full by automatically supplying any loss due to leakage or to contraction consequent upon a fall in the temperature of the oil.

3rd. Provision for the escape of the gases given off by the oil.

4th. Special precautions to prevent the passage of any of the oil into the boiler space.

The first vessel fitted with iron tanks for the marine transport of petroleum appears to have been the wooden ship "Charles," which was employed between the years 1869 and 1872 in the trade between the United States and Europe, for the transport of crude oil. Her capacity was 794 tons, and she was fitted with two rows of tanks in the hold and two rows in the 'tween decks—fifty-nine in all. The tanks were entirely unconnected, and there was no automatic arrangement for keeping them full, but salt water was run into those which were found to leak during the voyage. Several other wooden vessels were engaged in the bulk transport trade between America and Havre and Antwerp, but with little success.

The first *steamer* built especially for this trade was the "Faderland," which had a gross tonnage of 2,748, and was completed in 1872 by Messrs. Palmer & Co. This vessel and the similarly-constructed "Nederland" and "Switzerland," built in 1873 and 1874, were, however, never employed for the carriage of petroleum, and the first steamer actually employed in the transatlantic service was the "Fergusons," built by Messrs. Craggs & Sons in 1885.[1] The earlier employment of tank steamers in the Russian petroleum industry has been already referred to.

In September, 1885, Mr. L. V. Sone, of New York, obtained a patent for "Improvements in vessels for transporting liquid cargoes in bulk," and the system was successfully tested in the wooden sailing vessel "Crusader," of 643 tons, which was fitted up with forty-seven cylindrical tanks arranged in three superimposed tiers, and connected with a single expansion tank.

According to the specification of Mr. Swan's patent for improvements in the construction of "navigable vessels for carrying liquids in bulk, including cargoes of a volatile character such as petroleum,

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[1] This vessel was not built for the transport of petroleum in bulk, but was altered to adapt it for that purpose.

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turpentine, and the like," the hold is divided by a longitudinal bulkhead, and is further divided by a series of transverse bulkheads into compartments which are bounded above by the deck, or by a specially-constructed platform. Each compartment is fitted with one or more expansion trunks containing a float attached to a graduated rod which passes up through a stuffing-box and indicates the height of the liquid.

Mr. Swan has also patented an arrangement in which the water-ballast compartments, extending over the bottom of the vessel beneath the oil tanks, are each formed with the top sloping from the sides to the middle, where a large trunkway passing to the upper deck, is provided. By this device, the centre of gravity of the vessel is raised when in ballast, and lowered when in cargo, and the vessel is rendered perfectly seaworthy in either case. A further advantage claimed is that any oil which has entered the ballast space can be readily and effectively displaced by filling the tanks and trunks with water, the apex of each water-ballast compartment being so formed that the trunkway is situated at the highest point. The steamers "Glückauf" and "Vorwärts," each of 3,200 gross tonnage, and others, have been built by Armstrong, Mitchell & Co., in accordance with Mr. Swan's patents, but the two vessels named are constructed without the "conical" ballast compartments, their water-ballast tanks being situated fore and aft, and being supplemented when the vessel is in ballast, by filling some of the oil tanks with water.

In the steamship "Bakuin," built in 1886 by William Gray & Co., the bulk of the oil is carried beneath the lower deck. The outer sides of the tanks are formed by the sides of the ship, but the bottoms are independent of the ship's bottom. Additional tanks are built over the main tanks, but do not extend to the sides of the ship, a principle of construction which tends to preserve the bulk of the oil at a more equable temperature, while any injury to the hull, by collision or otherwise, would be less likely to injure the tanks.

In his paper of 1893, Mr. Martell gives drawings of two steamers in which the engines are placed respectively aft and amidships, and to which the most modern improvements have been applied. Plate XV. has been prepared from these drawings. To ensure that they shall always be full of oil, notwithstanding loss by leakage or diminution of volume due to decrease in temperature, the tanks are furnished with the oil trunks or expansion tanks shown, which also serve to hold a portion of the cargo when the volume of the oil is increased by a rise in temperature; while to entirely isolate the oil cargo from the engine and boiler space, double bulkheads or cofferdams are provided. The expansion tanks are usually capable of receiving about 4 per cent. of the oil in the storage tanks. When the engines are amidships, four instead of two cofferdams are provided.

This method of isolating the oil tanks was adopted in the earliest forms of tank steamers, but it is only recently that the importance of extending the cofferdam to the extreme height of the upper deck has been recognised. Greater security would be provided if there were no doorways piercing the bulkheads in the 'tween decks, but when they exist, the bottom of the doorway should be at least 18 inches above the main deck, and hinged doors, which can be screwed up oil-tight, should be provided. It is now usual to keep the cofferdams filled with water, although Mr. Swan considers the system open to objection, as it transfers the strain exerted by the oil, from the first to the second bulkhead.

Authorities were at first divided in opinion on the question whether the tanks should be formed of the skin of the ship or whether they should be independent, but the former construction is now always adopted.

As oil will leak through seams which are quite impervious to water, the very best workmanship and the utmost care in riveting are essential. It has been found that the rivets should be placed much closer together than usual, that the holes should conform well with each other, and that the "pan-headed" rivet with swollen neck under the head, is preferable to the "plug-headed" rivet formerly used.

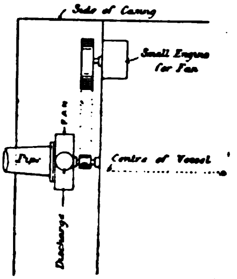
The scantlings of the framing and plating resemble those of ordinary cargo vessels, but the web-frames require to be more closely placed, and other details of construction have to be adopted to cope with the extra strain due to the constant movement of the cargo, whereby the weight is brought on directly from the plating to the side framing, instead of being mainly borne by the floor, as is the case with solid cargoes. On account of this extra stress, it has been found that a maximum length of tank of 24 feet cannot be safely exceeded unless special precautions be adopted to further strengthen the sides and the bounding bulkheads of compartments of greater length (*Martell*).

Where the engines are amidships, it is, of course, necessary to form a tunnel for the shaft, and in some instances the tunnel has been made double, an inner, gas-tight tunnel being formed, with an external one separated from it by a space of 18 inches, ventilated by ordinary cowls. This arrangement has been found objectionable, owing to the danger of escape of oil or gas into the space and thence through the inner tunnel into the engine room, and later vessels have been constructed with a single tunnel completely shut off by a cofferdam from the engine and boiler space. The single tunnel is made circular and oil-tight, and is fitted at each end with an oil-tight trunk extending to the upper deck to facilitate access.

The tunnel is ventilated by large cowls placed on the trunks, as shown in Fig. 177, a fan communicating with a perforated pipe which passes along the bottom of the tunnel, providing forced ventilation when required. A steam jet ventilator is also supplied for use in the event of the fan breaking down.

In respect to the question whether tank steamers are best fitted with the engines aft or amidships, Mr. Martell points out that the difficulty of trimming the earlier vessels constructed on the former system was so considerable, on account of the great and varying weight of fuel aft, that it led at one time to the general practice of placing the engines amidships. The initial expense, the decrease in cargo-carrying capacity, and the increased cost of maintenance which this entailed have, however, caused a very general return to the system of placing the engines aft.

As the oil tanks should be completely isolated from the cofferdams themselves, and from the spaces fore and aft beyond them, there should be a system of pipes and pumps solely for discharging the contents of the oil tanks, and the ballast tanks should admit of being emptied by means of a separate donkey-pump. There should also be a distinct means of draining the cofferdams. The oil suctions should of course be so arranged as to discharge the cargo as thoroughly as possible, and in modern tank steamers, very little oil remains in the tanks when the pump ceases to draw, the completion of the discharge



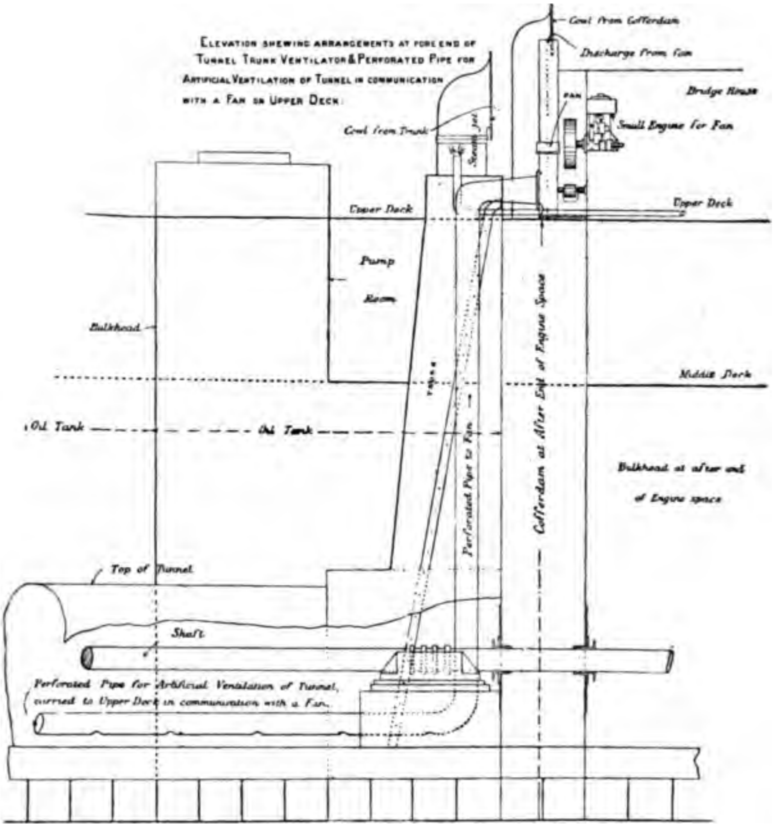

Elevation shewing arrangements at fore end of Tunnel Trunk Ventilator & Perforated Pipe for Artificial Ventilation of Tunnel in communication with a Fan on Upper Deck.
Cowl from Cofferdam
Discharge from Fan
Bridge House
Fan
Small Engine for Fan
Cowl from Trunk
Steam jet
Upper Deck
Upper Deck
Pump
Room
Bulkhead
Middle Deck
Oil Tank
Oil Tank
Trunk
Perforated Pipe to Fan
Cofferdam at After End of Engine Space
Bulkhead at after end of Engine space
Top of Tunnel
Shaft
Perforated Pipe for Artificial Ventilation of Tunnel, carried to Upper Deck in communication with a Fan.

Fig. 177.

being facilitated by emptying the tanks in such order, and by so trimming the ship, that the part of the tank where the suction is situated is the lowest. When repairs have to be effected in the tanks, a more complete removal of the oil is necessary, and for this purpose it is usual to fill the tanks with water to overflowing. It is therefore desirable that the construction of the tanks should be such as to admit, as far as possible, of the displacement of this residual oil by water.

Mr. Eldridge, in a paper read before the Institution of Naval Architects in July, 1891, on the "Weak Points in Steamers Carrying Oil in Bulk," &c., remarks upon the necessity for keeping the cofferdams which separate the oil tanks from the engine spaces, &c., filled with water, as well as the advisability of having them not less than four feet in width, in order that they may be readily cleaned and repaired. He condemns the practice of employing the oil pumps and piping for filling and emptying the foremost deep water-ballast tank, which may result in the passage of oil with the water into the tanks, and the consequent accumulation of gas without any means of escape, and insists that a separate donkey pump should be fitted forward, with suction and filling pipes for the deep water-ballast tank and fore peak.

When a volatile description of crude petroleum is transported, the tank covers should be fitted airtight, and each expansion trunk should be furnished with a vapour pipe of ample size, communicating with a main pipe carried into the hollow mast, or otherwise so arranged that the vapour given off by the oil is discharged at a safe elevation above the deck. If the vapour pipe is not of ample size, and there appears to have been a tendency to make it too small, an excuse is afforded for opening the tank covers during loading, to allow the displaced air to escape, or during discharge, to allow air to enter.

Mr. B. H. Thwaite[1] has suggested the use of a hydraulic or oil seal interposed between the expansion trunks and the vapour-discharge pipe, with a view to the prevention of passage of flame to the contents of the tanks in the event of the issuing vapour becoming ignited. Any diminution in the volume of the contents of the tanks, due to reduction of temperature, is compensated by injection of carbonic acid gas or, when an oil seal is used, by allowing oil to be drawn from the seal box. The jacketing of the tanks, or the provision of coils within them with a view to the use of a refrigerating agent to cool the oil when transport is taking place in a tropical climate, is also claimed in the same specification.

Efficient means of ventilating the tanks after the discharge of the cargo, are now usually provided, the arrangements shown in Fig. 176 and described as employed for the ventilation of the shaft tunnel, being similarly applied to the oil tanks. The general adoption of these appliances was recommended by the author in a report to a local authority in 1889. At the time of the "Tancarville" accident in 1891 (referred to later in this section), a portable exhaust-fan in connection with the ship's oil-discharge pipes was successfully employed, under the advice of the author, in ventilating the tanks of another steamer which was undergoing repairs in dry dock, the heavy vapour being thus drawn out from the bottom of the oil tanks while fresh air entered at the top. This system has been provided for permanent use on several recently-constructed tank steamships, and has been found to work well.

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[1] Patent No. 12,860, 1892.

Mr. Thwaite has further claimed in the above-mentioned patent the use of carbon dioxide for charging the cargo tanks as the oil is withdrawn by the pumps, so that the entrance of air is prevented and the risk of production of an explosive atmosphere is obviated. Although the large quantity of gas required for the purpose has been found to present a serious practical objection to the adoption of the system, it would facilitate the process of discharge of the oil if pressure could be applied to its surface by means of a compressed gas, for the vapours of the more volatile hydrocarbons and the dissolved gases present in crude petroleum, are given off under the influence of the necessary suction, especially when the level of the oil in the tanks is low, and the pump does not receive a full charge of oil. This additional advantage resulting from the introduction into the oil tanks of an inert gas under pressure, which apparently was not recognised by Mr. Thwaite, since no claim in respect to it is made in the patent referred to, led the author, in association with Mr. Lowick, to consider whether some suitable gaseous mixture less costly than carbonic acid might not be made available, but the necessary volume of even a far cheaper gas involves an expenditure which appears to be prohibitory.

As exemplifying modern improvements in petroleum tank steamers, reference may be made to the principal features of the "Delaware," completed in June, 1893, by Messrs. Dunlop & Co., for the Anglo-American Oil Company. This vessel is built of steel, has a gross tonnage of 3,855 tons, and is fitted with the engines aft. She is divided into ten separate compartments by transverse bulkheads, and these are divided by a longitudinal bulkhead running fore and aft through all the tanks. The cofferdams at each end of the oil space are 4 feet wide, and extend up to the spar deck. The expansion trunks are continuous, and extend for the full length of the ten double compartments from the main to the spar deck.

The pumping plant is of particular interest. The two main pumps were made by the Snow Steam Pumping-Engine Company of New Jersey, and are of the usual duplex type, each having a maximum output of 500 tons per hour. A cargo of 4,600 tons of oil may thus be discharged in a little over four hours; but it is usual to commence filling the forward tanks with water as soon as the oil has been discharged from them, one of the pumps being employed for that purpose. By this method of working, from ten to twelve hours suffices for discharging the oil and taking in water ballast.

The pumps are placed amidships, the floor of the pump-room being 7 feet below the main deck, and the greatest lift being about 21 feet. The main 10-inch pipe-lines run along the top of the vessel's floors on either side of the central bulkhead, and are continuous from the forward and after end tanks to the centre, where the two pipes connected with the forward tanks communicate with a vertical 12-inch pipe, those passing from the after tanks being similarly joined to another 12-inch pipe. These 12-inch pipes are connected with the two separate divisions of a suction-box, arranged—on a plan first introduced in the "Manhattan" tank steamer—in such a manner that the one box, which contains eight 12-inch valves, controls the suctions of both pumps, and enables them to do duty from any suction pipe.

The valve-box is so arranged that discharge may take place on either the port or starboard side, and the oil is pumped through four flanged pieces, two on each side of the spar deck, at a distance apart of about 26 feet. These pieces are provided with hinged bolts and portable covers, which can quickly be removed. The pipe-lines in the ship are connected with the various tanks by valves, the spindles of which pass up to the spar deck into sockets having screw caps, which cannot be affixed until the valves have been shut down. The two cofferdams and the forward ballast tank are pumped out by a separate "Snow" pump, which can also be employed to pump from the cofferdams into the oil tanks, so that any leakage of oil into the former may be saved. The water-ballast tanks are situated in the fore-peak, fore-hold, and under and abaft the machinery space in the poop.

The regulations laid down for the carriage of petroleum through the Suez Canal are as follows:—

Article 1.—Any ship laden with petroleum oil in bulk shall, on arriving before any port of access to the Canal, at once make herself known by flying at the mizzen one of the signals hereafter described, which shall remain flying during the whole of her transit.

Whenever any such ship makes any stay in port, she will be isolated by means of floating booms.

Article 2.—Before obtaining entrance into the Canal, the captain shall make a declaration to the following effect:—

(1) That his ship is specially classed for the carriage of petroleum oil in bulk, in Class ✠ A1 100 at Lloyd's in London, or in Class ✠ (I) 3/3 1.1. in the Bureau Veritas.

(2) That her cargo comprises refined petroleum oil only, of a uniform quality, no sample of which taken at the port of loading shall have given a flashing point below 23° C. (73° of Fahrenheit's thermometer), this temperature having been ascertained conformably with such process of close test as may be recognised and made use of in the petroleum oil trade, as for instance the Abel test or any other close test of a not lesser degree of accuracy;

(3) That her sole means of lighting, except the regulation apparatus for night transit and her mast lights, are electric incandescent lamps, and that all her electrical installations are in accordance with the rules of Lloyd's or Veritas;

(4) That the ship is provided with pumps intended solely for the loading and unloading of petroleum oil, and having an effective pumping capacity of 300 tons weight of oil per hour at a minimum;

(5) That no single tank in the ship has a cubic capacity greater than 200 tons measurement (being tons of 2·83 cub. metres, or 100 cub. ft. English) nor can discharge its contents into any adjoining tank through any aperture or want of continuity whatever of its walls;

(6) That no tank is placed either in the bows or stern of the ship;

(7) That the portion of the ship occupied by the tanks is completely separated from the forward and after parts by double oil-tight bulkheads forming spaces wholly filled with water.

Article 3.—Any ship laden with petroleum oil in bulk must be convoyed, during the whole of her transit through the Canal, by a tank-tug constructed with a view to the rapid and immediate lightening of the ship in case of grounding.

The Company reserve their right of approving before hand, the type and the dimensions of this tug, which shall, moreover, conform to all the provisions of §5, Art. 12. of the Regulations for Navigation.

The Company have a tank-tug which they will place at the disposal of vessels laden with petroleum in bulk passing through the Canal, whose captains may ask for it. The charge for hire will be in accordance with the provisions of §3 of Art. 12 of the Regulations for Navigation relating to convoying by a first-class tug.

Article 4.—During the whole of the transit through the Canal, the captain shall take care that no one on board shall smoke, nor have about the person any means of obtaining a light.

Article 5.—Any ship which, after having carried a cargo of petroleum oil in bulk may require to go through the Canal empty of oil, shall not be subject to the provisions of these provisional regulations; but her captain shall make a declaration to the effect that he has carried out all operations of cleansing, cleaning, or others, necessary to avoid the presence of any vapour from petroleum oil in the tanks, or in any other part of the ship.

Article 6.—All the provisions of the Regulations for Navigation and any appendix thereto, not contrary to the provisions of these provisional regulations, remain applicable.

Signals to be shown by ships carrying petroleum oil in bulk.

By day—A red flag above one ball.
By night—A white light between two red ones.

In his paper, read before the International Maritime Congress, July, 1893, Mr. Flannery has given the following account of the construction of tank steamers for the Suez Canal traffic:—The machinery is aft, the vessel is built on the three-deck rule, the cofferdams go right up to the weather deck, and the poop, bridge, and forecastle are so extended as to be only 8 feet apart. The sides of the vessel are carried up to the full height of the poop, bridge, and forecastle. This arrangement gives almost a complete double 'tween decks over the oil, and this, with double awnings over them, was considered a desirable precaution for so warm a climate.

The tanks are 34 feet long, the greatest length allowed, and are divided by middle line bulkheads, made without any openings whatever, and of sufficient strength to support the oil on either side should the other side become emptied from any cause.

The two bulkheads forming the after cofferdam are absolutely intact, and are divided along the middle line by an oil-tight and unperforated fore and aft bulkhead. Each cofferdam is fitted with its own separate pump, and its pipes and connections are independent of all others on the ship. The expansion trunks are capable of receiving 4 per cent. of the capacity of the oil space beneath, and are supplemented by large hatchways, with movable iron covers at the level of the tank top. When carrying general cargo homeward, these covers are removed, and the expansion trunks and hatchways give access to the 'tween decks and holds.

The oil cargo is dealt with by double pipe-lines placed just above the level of the floor, and as much as 450 tons of oil per hour has been discharged by this arrangement. One connection leads from these pipes to the oil pumps, with cross connections and valves, so that oil can be drawn from or delivered into any tank, and another separate connection from the same pipes leads to a large ventilating fan 6 feet in diameter, which also has cross connections, so that when the tanks are empty, air may be pumped into or out of them. This ventilating arrangement is of great benefit, and while carrying general cargo, the fan is worked for a short time each day to *draw* the air from the bottom of each hold, fresh air filtering down through the hatchways, so that cargoes of rice and other fine goods can be transported in perfect condition. In preparing the ship for receiving general cargo, after discharge of the oil, for the return journey, the tanks are charged with sea water, which carries the residual oil to its surface and floods it out through an opening in the expansion trunks. The water is then pumped out and fresh air is driven in, and when the air is sufficiently pure, men are sent down to clean out the tanks by hand and then to whitewash them and lay down a flooring.

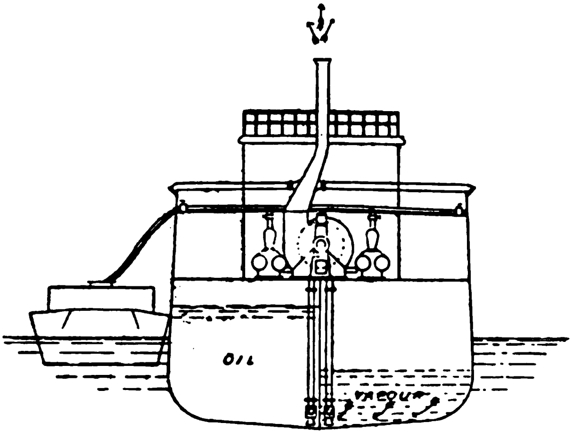

Fig. 178.

The difference in displacement of these vessels between North Atlantic winter and Indian summer load-line, is 500 tons, and, to provide for the extra draught allowed to the vessels in summer, a supplementary "summer" tank is arranged in the 'tween decks.

A method patented by Messrs. S. H. Terry and J. F. Flannery, for the ventilation of petroleum and other steamers, was described by them in a paper read before the Institution of Naval Architects.[1] It comprises means for drawing the air and vapour from the lower portions of the tanks or other parts of the ship by means of a fan, the pipes which serve for discharging the oil cargo being employed wherever possible. The fan preferred is of a type designed for the purpose by Mr. Chandler. It has a diameter of about 6 feet, and a width of 10 inches on the face, with a single inlet and reducing nozzle. The fan is driven by a single-acting engine, at 500 revolutions per minute. with a water-gauge of 12 inches, and a theoretical air velocity of 13,738 feet per minute. With such a fan, it has been found possible to renew the whole of the air in a 5,000-ton vessel in twenty-five minutes, or to change the air in a 400-ton tank once in two minutes.

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[1] *Engineering*, August 3, 1894, 181.

The engine and fan are situated aft of the pumps, oil-tight, double-seated valves being provided to connect and disconnect the pumps and fan as required. The vapour is discharged upwards, or right aft, or as shown in Fig. 178, a four-way flap-valve air trunk may be provided for diverting the issuing vapour to either side of the vessel if desired. The figure exhibits the discharge of oil from one tank, while the vapour is being withdrawn from another.

An improvement in the construction of petroleum tank steamers, recently invented by Mr. Henry F. Swan,[1] consists in the provision of one or more automatic expansion chambers above the tank deck. In carrying out this invention, a convenient arrangement is to provide two chambers, one towards the fore end and the other towards the after end of the oil space, which may be worked from the main oil-pump connections of the vessel for trimming purposes. The overplus from the main tanks caused by an increase in temperature is received in these tanks, and when the oil in the main compartments contracts, a supply is obtained automatically from the expansion chambers, the main compartments being thus always kept full.

The important question of the transverse stability of ships carrying oil in bulk has been dealt with by Mr. W. Hök in a paper read before the Institution of Naval Architects in March, 1895.

The enormous extent to which the system of bulk transportation has been adopted is shown by the lists of tank steamships and tank sailing-vessels employed in the trade, which are given in an appendix.

Explosions due to Ignition of Petroleum Vapour.—The causes and nature of the explosions which have occurred on the accidental ignition of a mixture of the vapour of the more volatile hydrocarbons with air, have an important bearing upon the principles of construction and management of petroleum tank steamers, and although it is impossible to deal fully with the subject in the space available in this work, the following particulars may be found of value. For further details reference may be made to a paper by the author on the "Transport of Petroleum."[2]

An explosion on H.M.S. "Hercules," resulting from the accidental fall and bursting of a cask of anti-fouling composition containing naphtha, in the forehold of the vessel, indicated, as early as 1870, the danger of allowing the vapour of mineral spirit to accumulate in admixture with air in a confined space; and in 1880, a similar accident occurred on board the steamship "Coquimbo." The destruction in 1881, of H.M.S. "Doterel," which resulted in great loss of life, was proved to be due to the blowing up of the gunpowder magazine, brought about by the explosion of a mixture of air with the vapour of petroleum spirit given off from a paint-drier known as "Xerotine siccative." In the same year, explosions arising from the use of this preparation happened on H.M.S. "Cockatrice" and on H.M.S. "Triumph." Leakage from a cask of paint containing coal-tar naphtha led to an explosion on the "Hawarden Castle" in 1884, and two years later, the employment on board the "Thorndike," of an anti-fouling composition, of which the same volatile liquid was an ingredient, caused a similar accident. Explosions on board the brigantine "Ruth" in 1871, and on the "Maria Lee" in 1873, were due in each case to the escape of benzoline from barrels containing that liquid.

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[1] Patent No. 4,898, 1894.

[2] *Minutes of Proc. Inst. Civ. Engineers*, cxvi.

The great travelling power of the heavy vapour of such hydrocarbons was well shown in the case of the Regent's Park explosion, which occurred in 1874 on the barge "Tilbury," carrying about 5 tons of gunpowder and four barrels of benzoline. Colonel Majendie proved that the explosion originated in the ignition of a mixture of benzoline vapour and air which found its way through the bulkhead to the fire in the cabin of the barge, having traversed a distance of from 35 to 40 feet.

In 1877, an explosion took place on the ship "Thomas," laden with petroleum spirit, and this was followed by many other similar accidents. In 1888, an explosion occurred near Woolwich, on the barge "Kohinoor," laden with pyrites, and this was apparently due to the fact that the barge had a short time previously carried a cargo of naphtha and had not afterwards been sufficiently ventilated.

The first serious accident on a petroleum tank steamer, occurred in 1886 on the "Petriana," a vessel having six oil tanks of a total capacity of about 2,100 tons, and water-ballast tanks beneath these. Having discharged a cargo of Russian kerosene of a flashing point of about 79° F. (Abel test), her tanks were being tested after certain repairs had been effected, by filling the forward water-ballast tank with water and attaching a vertical pipe filled with water to a height of about 30 feet, when an explosion, or rather an inaudible rapid ignition of an inflammable atmosphere, occurred in one of the oil tanks. Four persons were at once killed, and the remaining six who were in the tank at the time ultimately died. This accident differed from those previously recorded. The high flashing point of the oil rendered it improbable that inflammable vapour had accumulated at the low temperature then prevailing, and, moreover, men had previously been working with naked lights in the oil tanks and the water-ballast tank beneath. An investigation made by the author led him to submit the following explanation:—Some of the oil forming the cargo must have found its way into the water-ballast tank, where it would float upon the water therein. When the ballast tank was filled with water for testing purposes, the oil would be brought into contact with the underside of the floor of the oil tanks, and would be forced through any leaks existing, thus entering the tanks in the form of fine spray. In the position in which the vessel was lying, the tank in which the explosion occurred was at a higher level than the other oil tanks, so that any oil in the forward ballast tank would naturally lie beneath it.

It will be seen that this spray might accumulate until the atmosphere became inflammable and finally ignited at the naked lights used in the tank at the time. In experimenting with some of the petroleum in question, it was found that it was readily converted into a spray which remained suspended in the air and formed what may be described as a petroleum mist, which readily ignited even at a temperature of 50° F., and rapidly burned with an exceedingly hot flame. The accident was therefore due to the rapid combustion (not amounting to an audible explosion) of petroleum spray, and not to an ordinary ignition or explosion of a mixture of petroleum vapour and air.

The author's view was supported by the evidence of a witness who was in the tank shortly before the explosion occurred. This witness stated that there was a very strong smell of oil in the tank, which turned him giddy, made his eyes smart, and gave him a headache. About five minutes before the accident occurred he had noticed a defective rivet in the starboard tank, from which an oozing sound proceeded. The jury ultimately found a verdict in accordance with the above opinion, which was also supported in the *Annual Report of H.M. Inspectors of Explosives.*

In 1891, the s.s. "Lux," laden with a cargo of Russian refined kerosene, was lost in the Doro Channel, Grecian Archipelago. About 8.15 a.m. it was reported that there was a slight smell of kerosene in the bunker, and about 10 a.m. fire was found in the bilges, and shortly afterwards flames shot up through the bunker hatchways to a height of about 12 feet. The vessel was then abandoned, and owing to fog, was lost sight of, but during the night the ship's officers thought they heard two reports resembling guns or thunder or explosions, and the following day the vessel was found ashore, broken to pieces to an extent which the first mate thought could not be accounted for by the weather, but must have been due to an explosion.[1]

This accident was evidently due to the escape of oil from the expansion trunk of the cargo tanks into the port side bunker, and the overflow of this oil through the bunker into the stokehole, where, or in the bilges, it became ignited. The after cofferdam, which separated the oil tanks from the stokehole, was not carried up behind the side bunkers, but was contracted in the 'tween decks to the size of the trunks, and thus followed the section of the tanks and trunks. The side bunkers were each closed aft by an ordinary iron bulkhead having in it a hinged iron door about 3½ to 4 inches above the main deck, and furnishing therefore a sill of that height. The doors were not watertight, and were open during the voyage.

It is evident that any oil which entered the side bunker through leakage from the trunk would, notwithstanding the raised sill, be likely to find its way through the bunker into the stokehole, especially as the vessel was pitching in a heavy sea. This case, therefore, obviously indicates the importance of extending the cofferdam completely to the spar deck, or providing it with watertight doors, a system of construction which has since been adopted.

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[1] *Report to the Assistant Secretary, Marine Department, Board of Trade,* 5th March, 1892.

An accident which occurred in January 1890, on the river Wear, indicates the necessity for completely removing the cargo of oil from a vessel's tanks. The s.s. "Wild Flower" having carried a cargo of crude petroleum from Philadelphia to Rouen, arrived in the Wear with a portion of the oil still in her tanks, and this oil, or part of it, was discharged into the river in pumping out water ballast. The oil floated on the river and became ignited by some means, with the production of a fierce fire, by which one man lost his life, and several ships were injured.[1]

The following accounts refer exclusively to the explosion of mixtures of the vapour of American *crude* petroleum and air on board tank steamers :—

In October 1888, an explosion occurred at Calais, on the s.s. "Ville de Calais" which had just discharged her cargo. One of the empty tanks was being filled with water for ballast, and the mixture of air and petroleum vapour contained in the tank was thus being expelled, and became ignited, with the result that an explosion occurred which destroyed the ship, killed several persons, and did much damage to surrounding property. The hinged cover of the tank was open during the pumping-in of the water, and it was to this that the ignition was undoubtedly due. The vessel had a main vapour pipe 2½ inches in diameter laid on deck, with a branch into each expansion trunk and terminating in the hollow iron foremast. Had the tank lid been closed, the displaced vapour would therefore have been safely discharged at the masthead.

In December 1889, an explosion occurred on the s.s. "Fergusons," a vessel which had not been constructed for the petroleum trade, but had been fitted with thirty-two tanks with four regulating tanks. The accident may be attributed to the ignition of an explosive mixture of petroleum vapour and air in the hold of the vessel. The discharging arrangements necessitated the opening and shutting of cocks in the suction pipes below deck, and one of the crew was performing this duty when the explosion occurred. The ignition was ascribed to the accidental production of an electric spark in the space in the hold of the vessel in which the cocks were situated, artificial light being furnished by incandescence electric lamps.[2] There were, according to the evidence, two explosions, the first wrecking the vessel and setting fire to the after part, and the second, occurring after an interval of about an hour and a quarter, during which the vessel had been burning, completing the destruction of the hull and liberating a quantity of burning petroleum.

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[1] *Report to the Assistant Secretary, Marine Department, Board of Trade*, March 7, 1890.

[2] *Report to the Assistant Secretary, Marine Department, Board of Trade*, February 17, 1890.

On the 11th May, 1891, an explosion occurred on the s.s. "Tancarville," which had shortly before discharged a cargo at Havre, and was in dry dock at Newport, Monmouthshire. The vessel had been under repair for twenty days when the explosion took place. From an examination made by the author on the same day, it appeared that the explosive force had been mainly localised on the port side of a water-ballast tank, immediately forward of No. 1 oil tank, and had been exerted principally upwards and aft. Before the work of repairing was commenced, the oil tanks were cleaned by a jet of water, and were afterwards dried with sawdust and cotton waste. They were ventilated by windsails before, during, and after the cleaning. The water-ballast tank had not been used since October, 1890, as a cargo tank, but it was asserted that while a cargo of crude oil was being discharged at Havre in February, 1891, some one from the shore opened a valve and allowed a quantity of oil to flow into the ballast tank. The suction pipes were so arranged that the water could not be drawn from the ballast tank beyond a depth of 4½ inches from the bottom. After discharging her last cargo, the ballast tank had been filled with water, but if an attempt had been made to displace the oil by water and cause it to overflow into the 'tween decks, a considerable quantity of oil would have been confined between the beams in the upper part of the tank, and prevented from flowing away. The vessel was lighted throughout by electric incandescence lamps, but several portable forges were in use on the upper deck during the repairs.

On the morning of May 11, men were sent into No. 1 oil tank, adjoining the water-ballast tank already referred to, to clean up some oil which had leaked in through a defective rivet hole in the bulkhead separating the tanks in question, and the work of repairing in the tank was then continued. As one of the workmen was cutting a thread, with a view to replacing a defective rivet by a screw plug, a tongue of flame appeared to issue from the hole. The flame then seemed to recede, and immediately a very violent explosion occurred, killing four men, injuring others who were in the tank, and killing a carpenter who was in the 'tween decks, on the port side over the bunker space. The explosion was undoubtedly due to the ignition of a mixture of air and petroleum vapour in the ballast tank, but the actual cause of the ignition was not ascertained.[1]

Samples of the petroleum were examined by Dr. Dupré and the author, and it was found that 1 gallon would render 200 cubic feet feebly, and about 58 cubic feet of air strongly explosive. The capacity of the ballast tank was about 6,000 cubic feet, so that 20 cubic feet of the oil would render its atmosphere explosive.

It seems probable that the atmosphere on both sides of the ballast tank was not equally explosive. The tank was divided centrally by a vertical fore and aft bulkhead, and if the existence of a merely inflammable atmosphere on the starboard side of this bulkhead, and of a violently explosive mixture on the port side be assumed—a condition of things which is consistent with the statement that the manhole on the starboard side was open, while that on the port side was closed—it is easy to understand that there may have been first an ignition of the contents of the starboard compartment, producing the flame which passed through the rivet hole into the tank where the men were working, and afterwards an explosion of the contents of the port compartment.

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[1] *Report to the Assistant Secretary, Marine Department, Board of Trade,* 31st July, 1891.

It is possible that the ignition originated in the bunker above the ballast tank. This space was provided with a central hatchway, and the expansion trunks of the ballast tanks, which opened into the bunker, were not beneath the hatchway, but to port and starboard respectively. It is difficult to understand how, with an open hatchway of considerable size, there could have been in the bunker any large accumulation of vapour which had diffused into it from the ballast tank, but it should be remembered that on the morning of the explosion the sun was shining brightly, and the weather was warmer than it had been just previously. The atmosphere of the ballast tank was therefore probably undergoing rapid expansion under the influence of the elevation of temperature, and it is conceivable that an inflammable or explosive mixture of petroleum vapour and air may have been overflowing into the bunker.

On June 13, 1892, an explosion, attended with the loss of several lives, occurred on the s.s. "Petrolea" during the discharge at Blaye, near Bordeaux, of a cargo of 2,800 tons. The oil tanks were fitted with 3-inch air pipes extending from the expansion trunks, but these were not connected with the mast, as in the case of the "Ville de Calais," and the manhole covers appear to have been raised during the discharge of the oil. In the absence of any other explanation, it was suggested that, as a thunderstorm occurred shortly before the explosion, the mixture of petroleum vapour and air might have been ignited by lightning.[1]

On the 4th of November, 1892, the iron sailing ship "Norcross," coming from Philadelphia to Rouen with a cargo of 2,300 barrels of crude petroleum and 3,300 barrels of mineral naphtha, was blown up in the Seine near Honfleur. While she was proceeding up the river in tow, a sailor, standing on the ladder leading through the upper forepeak to the hatchway into the lower forepeak struck a match, and this was immediately followed by a rush of flame and a violent explosion. The fact that an explosive atmosphere existed in the forepeak, points to the conclusion that petroleum vapour must have travelled from the hold, through the collision bulkhead, into the forepeak.[2]

An explosion occurred at Cardiff, in December, 1892, on board an ordinary cargo steamer, the "New York City," which had previously discharged a cargo of crude petroleum in barrels at Rouen. The explosion was inaudible and did not damage the vessel, but three men were injured by burning. The ignition took place in the deep ballast tank, which had, however, been previously flushed with water. The oil had evidently leaked from the barrels, and, notwithstanding the flushing, the atmosphere had remained inflammable, for on the entrance of men with a naked light, the ignition occurred.

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[1] The fire which occurred on the 31st May, 1895, at a petroleum storage installation at Harburg, appears to have originated in the ignition, by lightning, of the gaseous contents of a large tank. The tank contained at the time only a small quantity of oil, the flashing point of which was 107° F. (Abel test).

[2] *Report to the Assist. Secretary, Marine Department, Board of Trade*, 9th December, 1892.

Experimental Investigation relating to the Formation of Explosive Mixtures of Petroleum Vapour and Air.—The accidents described, indicate clearly that certain descriptions of petroleum evaporate freely at common temperatures; that the vapour given off is much heavier than air, and may remain for a considerable length of time in any receptacle capable of holding a liquid, or may flow unperceived for some distance in a stream similar to that of a liquid; that the vapour is highly inflammable and capable of carrying back flame to the source whence it emanated; and that mixtures of petroleum vapour and air may be either inflammable (burning silently) or more or less violently explosive. The experience in one case, further shows that petroleum, at temperatures below that at which inflammable vapour is freely evolved, may be readily converted into a highly combustible spray.

It will be noted that, with the exception of the cases of the "Petriana" and "Lux,"[1] the accidents recorded have been due to the presence of vapour given off by crude petroleum, by petroleum spirit (benzoline), or by coal-tar naphtha. It must not, however, be assumed that all precautions which have reference to the possible accumulation of vapour, are unnecessary in the case of refined petroleum oil (kerosene). Crude petroleum consists almost entirely of a mixture of a great number of hydrocarbons, differing in boiling point and density. It is principally composed of carbon and hydrogen, usually in the proportion of about 85 parts by weight of the former, and 15 of the latter. Some descriptions of crude petroleum contain exceedingly volatile liquid hydrocarbons, which are separated in the process of refining, and are met with in commerce as gasoline, benzoline, &c., and even dissolved gaseous hydrocarbons, which are readily liberated. It is therefore not surprising that a portion of such crude petroleum freely evaporates. The density of the vapour given off by petroleum is dependent upon the chemical composition of the hydrocarbons volatilised. Thus, the vapour of pentane (C_5H_{12}), a hydrocarbon of the paraffin series, present in American crude petroleum, and of which gasoline is largely composed, is 2·5 times heavier than air, while that of heptane (C_7H_{16}) is 3·4 times heavier. The great density of petroleum vapour may be shown by allowing a small quantity of gasoline to evaporate in a glass jar, and decanting the vapour into another vessel, to which a flame may be afterwards applied. It will be found that the vapour has been poured from vessel to vessel almost as readily as if it had been a liquid.

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[1] To these must now be added that of the fire at Harburg (see note 1 on preceding page), which occurred after this section was written.

In connection with the loss of the "United," and with the object of demonstrating the facility with which the vapour of benzoline diffuses into air, and in that operation makes its way through small openings, such as may exist in a bulkhead for instance, Dr. Dupré performed the following experiment:—A small quantity of petroleum spirit (benzoline) was placed in a cigar-box having all its edges but one closed by paper pasted over it, the paper joints having by a previous experiment been proved to be vapour proof. This box was placed inside a larger box, and a small glass tube conducted from the interior of the inner to the outside of the outer box. About one hour sufficed to render the atmosphere in the outer box inflammable, and forty minutes after this had been flashed off, a light was applied to the mouth of the glass tube, when a sharp explosion occurred in the outer box. Evidently the vapour in the inner box was ignited in this second test, but being somewhat in excess no explosion occurred in that box, but the flame passed through the narrow slit and exploded the mixture in the outer box.[1]

The crude petroleum which had been carried in the "Tancarville" prior to the accident of which particulars have been given, had a specific gravity of 0·799 at 60° F., and it commenced to boil at 120° F. Experimenting with this oil in a vessel intended to reproduce on a small scale the conditions existing in the ballast tank, but having unintentionally a somewhat larger opening at the top, Dr. Dupré found that the oil lost by evaporation, 2·03 per cent. on the first day, 1·53 per cent. on the second day, 1·14 per cent. on the third day, and only 0·98 per cent. on the fourth and fifth days combined, the fifth being a Sunday. The temperature ranged from 60° F. to between 70° and 74° F. The air in the vessel was explosive at the end of the fifth day, and half an hour after the first explosion, it was again explosive. In making this experiment, it was observed that the vapour tension of the oil soon stopped evaporation, so that the air over the oil never became more than about violently explosive. One volume of the oil was found to render 1,150 volumes of air inflammable, and about 350 volumes of air strongly explosive.

Mr. J. H. Heck, in a paper read before the Institution of Naval Architects, in April, 1892, gave the results of a large number of experiments made to ascertain the conditions under which an explosive atmosphere is produced in an enclosed space, from petroleum spirit and crude and refined petroleum.

With petroleum spirit, and nearly all the samples of crude petroleum examined, an inflammable or explosive atmosphere was formed at temperatures from the freezing point of water upwards; but with American and Russian refined oil (presumably kerosene), no inflammable or explosive atmosphere could be formed, even in the absence of ventilation, at temperatures up to 70° F. At temperatures much above 80° F., and with no ventilation, such an atmosphere could be produced with a number of the samples. Of three samples of crude petroleum examined, one volume would render explosive about 180, 400, and 600 volumes of air respectively.

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[1] *Report to the Right Hon. the Secretary of State for the Home Department*, 21st December, 1888.

The following are details of some of the experiments, which were conducted at temperatures ranging from 55° to 65° F.:—

1. Vertical tube, 6 inches diameter, 6 feet high, containing explosive atmosphere and $1\frac{3}{4}$ per cent. of crude oil; open hatchway area at top $\frac{1}{84}$ of bottom surface of oil; at end of seven days atmosphere found explosive at bottom; open hatchway area then increased to $\frac{1}{18}$ of bottom surface of oil; five days afterwards, atmosphere at bottom found still inflammable.

2. Vertical tube, 6 inches diameter, 6 feet high, containing explosive atmosphere and $1\frac{1}{2}$ per cent. of crude oil; open hatchway area at top $\frac{1}{84}$ of bottom surface of oil; at end of seven days atmosphere found explosive at bottom; open hatchway area then increased to $\frac{1}{9}$ of bottom surface of oil; four days afterwards atmosphere at bottom found still inflammable.

3. Vertical tube, 6 inches diameter, 6 feet high, containing explosive atmosphere and $1\frac{1}{2}$ per cent. of crude oil put in through thistle-tube; open hatchway area at top $\frac{1}{9}$ of bottom surface of oil; atmosphere at bottom found inflammable five days afterwards.

4. Tank, 18 inches by 14 inches, containing explosive atmosphere and 2 per cent. of crude oil; open hatchway area at top $\frac{1}{50}$ of bottom surface of oil; at end of seven days atmosphere at bottom found still explosive; hatchway area at top then increased to $\frac{1}{20}$ of bottom surface of oil; eight days afterwards atmosphere at bottom found still inflammable.

5. Tank, 9 inches by 7 inches, containing explosive atmosphere and 2 per cent. of crude oil; open hatchway area at top $\frac{1}{50}$ of bottom surface of oil; at end of fifteen days atmosphere at bottom found still inflammable.

In all the vessels used, small tubes were fixed, standing a short distance above the bottom, and having a clear section of $\frac{1}{144}$ of the bottom area. When these tubes were opened, and the hatchway area at the top made $\frac{1}{72}$ of the area, an inflammable or explosive atmosphere could be quickly purified. The atmosphere in a vertical tube, 6 inches in diameter and 6 feet high, full of explosive vapour, and containing about 2 per cent. of average crude oil, could be more effectually cleared of vapour in the course of one hour by openings at the bottom and top, having areas respectively of $\frac{1}{144}$ and $\frac{1}{72}$ of the bottom surface, than it could in the course of ten days by means of an opening at the top $\frac{1}{50}$ the area of bottom surface. The experiments indicated that the data obtained with small models were not in all respects trustworthy indications of what would take place in a large tank, but the results, as a whole, are not without interest.

Dr. Dupré has estimated that, in order to prevent the production of an explosive or inflammable mixture in a tank containing such crude petroleum as formed the cargo of the s.s. "Fergusons," the accident on which has been already described, it would be necessary to have ventilation equivalent to 120 cubic feet of air per hour for every square foot of oil surface exposed. If the oil were spread out in a thin layer, the air current required would amount to about 200 cubic feet per minute for each gallon of oil. The volume of air required varies, of course, with the volatility of the oil, and the prevailing temperature of the air and oil.

In the course of a series of experiments which the author made in investigating the circumstances attending the disastrous ignition of the vapour given off by indiarubber solution on the premises of a hat and helmet manufacturer in Cloth Fair, London, 1890, it was found that a sample of the mineral naphtha employed in preparing the solution, gave off inflammable vapour freely at zero Fahrenheit. One pint of the liquid, poured over a level surface, covered an area of about 80 square feet, and at a temperature of 60° F. this quantity evaporated in four minutes and rendered 100 cubic feet of air violently explosive. A piece of sponge saturated with the spirit was placed at one end of a covered zinc channel 5 feet in length, and 25 square inches in area transversely, a small stationary flame being provided at the other end. In sixty-eight seconds, the vapour had travelled from the sponge along the level floor of the trough to the flame, where it immediately ignited, and in one second more, the flame had travelled back to the sponge and ignited the liquid. When a gentle current of air was caused to flow through the apparatus away from the sponge, the vapour was carried to the flame in twenty seconds.

A description of a series of experiments conducted by the author and Mr. Blundstone, in order to gain further information as to the manner in which crude petroleum and various petroleum products evaporate, will be found in the section relating to the uses of petroleum.

In connection with the destruction of the "United," Dr. Dupré carried out experiments with a view to determining the proportions of petroleum spirit (benzoline) vapour and air requisite for the production of inflammable and explosive mixtures, and found that one volume of benzoline will render 16,000 volumes of air inflammable, 5,000 volumes strongly explosive, and 3,000 inflammable, but scarcely explosive. Similar experiments made by the author demonstrated that, when the vapour given off by crude petroleum, or by a freely volatile product of petroleum, is allowed to diffuse into air in a confined space, the atmosphere first becomes gradually converted into an inflammable mixture which ignites and burns rapidly, but without any audible explosion. As the proportion of vapour to air increases, there is a corresponding acceleration in the transmission of flame through the gaseous mixture, accompanied by a gradually augmenting volume of sound, until the proportions necessary for the production of the most violent explosion are reached. Beyond this point, any increase in the proportion of vapour is accompanied by a diminution in the energy of the combustion, and an increase in the duration of the flame. The mixture, therefore, becomes first inflammable but not explosive, next explosive, and finally again only inflammable. It is also found that during the progress of the diffusion of vapour from a layer of petroleum at the bottom of a tank into the air in the tank above the liquid, the proportion of vapour in the atmosphere is not uniform throughout, unless the gaseous contents of the tank are mixed by agitation, the greater proportion of vapour being at the bottom.

The experimental determination of the respective volumes of a given description of petroleum required for the production, with a given volume of air, of gaseous mixtures, which under given conditions are (*a*) just inflammable, (*b*) violently explosive, and (*c*) again only inflammable, can be effected with tolerable facility with some kinds of petroleum and under certain conditions of temperature; but the bulk of the mixture, or, in other words, the scale on which the tests are made, and the method of ignition adopted, are not without material effect upon the results. Thus, the introduction of a large flame may bring about the combustion of a mixture containing a small proportion of vapour which a small flame will not ignite, and a mixture which burns silently in small bulk may be consumed with a rapidity approaching to explosive violence when a large volume of it is ignited. In the case of a liquid of uniform composition wholly volatilising with freedom at common temperatures, such as pentane, it is obviously not difficult to introduce gradually increasing volumes into a given volume of air and test the character, as to inflammability, of the resulting gaseous mixtures; but with crude petroleum, which is of variable composition, and of which only a small proportion passes into vapour by a process of fractional evaporation, and even with a less complex liquid such as commercial benzoline, it is by no means an easy matter to make experiments the results of which would be of much practical value except as a basis for comparison.

A series of experiments has recently been carried out by the author, with the assistance of Mr. Blundstone, with the object of ascertaining the character, as regards inflammability, of mixtures of air with the vapour of crude petroleum and of certain of the more volatile products of petroleum in various proportions. The apparatus employed consisted of a glass cylinder or churn capable of being rotated at right angles to its longitudinal axis, an arrangement for displacing a known volume of the gaseous contents of the churn by admission of the required volume of the liquid under examination, and an explosion chamber in which the character of the combustion of mixtures of the air-gas produced in the churn, and of air in various proportions, were tested. The explosion chamber consisted of a square vessel of stout tinplate, 1 cubic foot in capacity, with an agitator for mixing the contents, a loose cover with a water seal, tubulures for the introduction of the air-gas and escape of the displaced air, and a circular vent 3 inches in diameter, through which the igniting flame was introduced.

In performing the test, a quantity of the liquid to be evaporated was poured into the churn, which was then rotated for a time. After relieving the pressure produced by the volatilisation, by permitting a portion of the gaseous contents of the churn to pass into the displacing arrangement, a known volume of the gas was driven into the explosion chamber. This chamber was then disconnected from the churn by closing a tap, its contents were mixed by means of the agitator, the vent was opened and a flame was applied.

TABLE LVI.—EXPERIMENTS WITH PETROLEUM SPIRIT.

Percentage by volume of Air-Gas to Air in Explosion Chamber.	Gasoline. Specific gravity 0·689. Temperature 68° F.	Petroleum Spirit. Specific gravity 0·680. Temperature 65° to 68° F.	Petroleum Spirit. Specific gravity 0·700. Temperature 65° to 68° F.
2·0	No ignition.	... ...	... ...
2·0	Experiment repeated in darkness with similar result.	... ...	... ...
2·5	Very slight indication of explosion. Lambent blue flame slightly issuing from vent. Cover, weighted with 7 lbs., not raised.	... ...	... ...
3·5	Mild explosion. Small blue flame emitted from vent. Cover, with 7 lbs. weight, slightly raised.	No ignition.	No ignition.
4·0	Somewhat violent explosion. Cover, with 7 lbs. weight, lifted.	Lambent blue flame. Ignition extending slowly.	Ignition extending very slowly. Lambent blue flame.
4·5	... ...	... ...	Explosion. Cover, weighted with 7 lbs., slightly raised.
5·0	Very violent and sharp explosion. Cover, with 7 lbs. weight, lifted, and flame issuing between it and box. Long pale blue flame emitted from vent.	Mild explosion. Cover, with 7 lbs., scarcely lifted.	Violent and rapid explosion. Cover, with 7 lbs., slightly lifted.
6·0	Very violent explosion. Cover, with 11 lbs. weight, lifted.	... ...	... ...
7·5	Very violent explosion. Cover, with 7 lbs. weight, lifted, and flame emitted from vent scorching at distance of 3 feet. Experiment repeated with 11 lbs. weight. Very violent explosion, but cover scarcely raised.	Somewhat violent explosion.	Explosion more violent than with 5 per cent.
8·0	Violent explosion. Cover, with 11 lbs. weight, slightly lifted.	... ...	... ...
8·5	Cover, with 11 lbs. weight, moved but not lifted. Long flame with tendency to luminosity emitted from vent, ignition terminating in explosion.	... ...	... ...

TABLE LVI.—*Continued.*

Percentage by volume of Air-Gas to Air in Explosion Chamber.	Gasoline. Specific gravity 0·639. Temperature 68° F.	Petroleum Spirit. Specific gravity 0·680. Temperature 65° to 68° F.	Petroleum Spirit. Specific gravity 0·700. Temperature 65° to 68° F.
10·0	Long flaring luminous flame. Ignition merging into slight explosion. Cover, weighted with 7 lbs., not lifted though moved.	Violent explosion. Cover, weighted with 7 lbs., lifted about 2 inches.	Very violent explosion. Flame issuing round cover as well as from vent.
11·0	Gentle combustion. Luminous flame, 18 inches to 2 feet, issuing from vent. Cover, with 7 lbs., not lifted.	Explosion rather more violent than with 10 per cent.	... ...
12·5	... ...	Explosion less violent than with 10 per cent. Cover, with 7 lbs., scarcely raised. Long flame issuing from vent.	Extremely violent explosion. Flame from vent scorching at a distance of 2 to 3 feet.
14·0	... ...	Flame (luminous at first, then pale blue) issuing from vent to a distance of a yard. Cover, with 7 lbs., not lifted.	... ...
15·0	... ...	Gentle combustion. Luminous flame burning quietly at vent. Cover, with 7 lbs., not lifted or moved.	Long flaring flame with some luminosity. Cover, with 7 lbs., not lifted.
20·0	... ...	... ...	Gentle combustion. Luminous flame, burning quietly at vent. Cover, with 7 lbs., not raised.

Note.—With the gasoline (0·639), the minimum percentage of air-gas requisite to produce an incipient explosion, was 2·5, while the maximum was from 10 to 11.

With the petroleum spirit (0·680), the minimum was between 4 and 5, and the maximum 15.

With the petroleum spirit (0·700), the minimum was also between 4 and 5, but apparently nearer to the former percentage than was the case with the 0·680 spirit. On the other hand, the maximum was higher, viz., 20. It is possible that the lower minimum may have been due to the presence in the 0·700 spirit, of a very small proportion of very volatile hydrocarbons, which were absent from the 0·680 spirit.

The conditions under which the air-gas was made from the hydrocarbons, were substantially similar in the three sets of experiments, and the results are, therefore, fairly comparable.

The flame of a taper was, in each experiment, used to test the mixture.

TABLE LVII.—EXPERIMENTS WITH CRUDE AMERICAN PETROLEUM AIR-GAS.
Temperature 75° F.

Percentage by volume of Air-Gas to Air in Explosion Chamber.	Results obtained on Testing the Mixture with the Flame of a Taper.
15·0, . . .	No ignition.
16·0, . . .	Sluggish explosion gradually increasing in violence. Flame issuing from vent to a distance of 4 inches. Unweighted cover not raised.
20·0, . . .	Sluggish ignition. Pale blue flame issuing from vent to a distance of 10 or 12 inches. Cover, weighted with 14 lbs., not raised but shaken.
25·0, . . .	Instantaneous and violent explosion. Cover, with 4 lbs., lifted 2 inches at corner; with 14 lbs., not raised.
33·5, . . .	Violent explosion. Cover, with 14 lbs., lifted.
37·0, . . .	Violent explosion. Cover, with 14 lbs., lifted.
50·0, . . .	Perhaps even more violent explosion. Cover, with 14 lbs., lifted.

Note.—The air-gas used in the above experiments, when ignited in a 500-cubic centimetre jar, burned with a flame which was at first of comparatively feeble luminosity, and afterwards, shortly before its extinction, of a blue colour.

TABLE LVIII.—EXPERIMENTS WITH PENTANE AND GASOLINE EVAPORATED IN EXPLOSION CHAMBER.

Weight on cover = 8 lbs. Temperature, 65° F.

Volume of Liquid to 100,000 volumes of Air.	Per cent. of Vapour.	Results obtained on Testing the Mixture with the Flame of a Taper.
3·5	0·672	No ignition.
5·6	...	,,
5·95	...	Slight combustion round large flame.
6·3	...	More marked combustion round flame.
6·65	...	Very sluggish combustion, extending through the mixture.
7·0	1·345	Quiet combustion, scarcely audible; duration about two seconds.
7·7	...	Hissing sound; water blown out of seal; cover not lifted.
8·4	...	Hissing sound; water blown out of seal; cover barely lifted.
9·1	...	Louder hissing sound of shorter duration; cover lifted.
9·8	...	,, ,, ,, ,,
10·5	2·017	Sharp explosion.
11·2	...	,,
11·9	...	,,
12·6	...	,,
13·3	...	,,
14·0	2·690	,,
14·7	...	,,
15·4	...	,,

TABLE LVIII.—*Continued.*

Volume of Liquid to 100,000 volumes of Air.	Per cent. of Vapour.	Results obtained on Testing the Mixture with the Flame of a Taper.
16·1	...	Sharp explosion.
18·8	...	,,
17·5	3·362	Slightly less violent explosion, but cover lifted, and outburst of flame.
18·2	...	,, ,, ,, ,,
18·9	...	,, ,, ,, ,,
19·6	...	Roaring sound; cover slightly lifted.
20·3	...	,, ,, ,,
21·0	4·034	Prolonged roaring sound; cover practically not lifted.
28·0	5·379	Mixture ignited silently at vent, and flame then travelled into the chamber, where the mixture continued burning quietly for three seconds.

Note.—With 7 volumes of the liquid to 100,000 volumes of air, the combustion is a silent one, while with four times that proportion of liquid, the mixture also burns without explosive violence. With between 8 and 9 volumes of liquid to 100,000 of air, there is a marked increase in the energy of the combustion, and when the quantity of liquid is augmented to 10·5 volumes, a sharp explosion occurs. When the proportion of liquid is increased beyond about 17 volumes, there is a perceptible decrease in the violence of the explosion, with corresponding gain in the volume and duration of the flame, and with 21 volumes of liquid to 100,000 of air, the explosion is as mild as with 8·4 volumes.

Some of the results obtained in the manner described on p. 509, are given in Tables LVI. and LVII., while Table LVIII. records those yielded by a series in which various volumes of liquid pentane and commercial gasoline were introduced directly into the explosion chamber by means of a graduated pipette.

As the strength of the explosion chamber was not sufficient to permit of heavily weighting the cover, it was impossible to differentiate between the explosive force exerted by the combustion of several of the mixtures. It will be observed that, comparing the results obtained by use of the "churn," with those obtained by direct evaporation in the explosion chamber, there is in the latter case a smaller difference between the proportion of vapour required for the production of an inflammable mixture, and that necessary for obtaining a mixture exploding with the maximum violence. This apparent discrepancy may, however, be due to the limited scope which the conditions of the experiments afforded for recording the results with any approach to precision, when a more or less violent explosion occurred.

In the case of a petroleum product of known chemical composition, there is, of course, no difficulty in ascertaining, by calculation, the proportions of vapour and air requisite for the production of the most violent explosion, if we assume that in such case the hydrocarbon is burned to carbon dioxide and water. Thus, in the case of pentane (C_5H_{12}), we find that 1 cubic foot of air at 60° F., and 30 inches barometric pressure, is required for the conversion of 34·5 grains (3½ cubic centimetres at 60° F.) into CO_2 and H_2O. This is equivalent to 12·25 volumes of liquid to 100,000 volumes of air, and on referring to Table LVIII., it will be seen that these proportions gave, in the author's experiments, a violent explosion.

The successive stages of (1) uninflammability, (2) silent combustion, (3) more or less violent explosion, (4) silent combustion, and (5) uninflammability (except on the surface exposed to the air), occurring during the addition to air, of increasing proportions of petroleum vapour, are similar to those which have been observed in experiments with mixtures of combustible gases and air. Thus, it has been ascertained that, if to the violently explosive mixture of two volumes of hydrogen and one volume of oxygen, eight volumes in excess of hydrogen, or nine volumes in excess of oxygen, be added, the mixture is rendered non-inflammable, provided that the temperature of the gases does not exceed 18° C., and the pressure is not above 14·7 pounds per square inch. A mixture which is not, under such conditions, combustible, may, however, be brought into an inflammable state by increase of temperature or pressure, and it has been found that flame may be propagated through a mixture, which by an ordinary test would appear to be uninflammable, by projecting into the mixture a considerable volume of burning gas, in consequence of the resulting increase of temperature and pressure. Messrs. Mallard and Le Chatelier also ascertained that the rate of propagation of flame through an inflammable gaseous mixture was affected, not only by the temperature and size of the igniting flame, but also by the mechanical agitation or disturbance of the mixture itself. These results are not surprising when it is considered that it is necessary, for the spread of combustion in an inflammable gaseous mixture, that the temperature of the combustion should be sufficient to ignite the uninflamed portion. According to Messrs. Berthelot and Vieille, when an explosion of a gaseous mixture occurs, a number of ignited molecules are projected forward with a velocity corresponding with the maximum temperature produced by the chemical combination, the impact causing the ignition of the adjacent particles, and the rate of progression of the combustion being thus dependent upon the activity of the chemical action. The experiments made by Mr. Hirn with the view of determining the pressures resulting from the explosion of gaseous mixtures in closed vessels showed that there was a considerable difference between the theoretical and observed results, which he ascribed to the cooling effect exerted by the walls of the containing vessel. Similar differences were observed by Mr. Dugald Clerk.[1] Messrs. Berthelot and Vieille also ascertained experimentally that the reduction of pressure due to loss of heat by radiation and absorption by the walls of the vessel is in proportion to the area or surface of the vessel, in relation to the volume of gaseous mixture, and to the slowness of the combustion.

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[1] *Min. of Proc. Inst. Civ. Engineers*, lxxxv., 1.

With petroleum oil (kerosene), it is difficult to produce on a small scale an inflammable mixture of vapour and air at temperatures more than a very few degrees below the flashing point (Abel test) of the oil, even when vigorous agitation is resorted to; but when large volumes of the oil are violently agitated, as in the operation of pumping from one tank to another, vapour appears sometimes to be disengaged at a somewhat lower temperature. The result may, in part at anyrate, be due to the liberation of traces of gaseous hydrocarbons dissolved in the oil. With such opportunities for the diffusion of the vapour as ordinarily exist during the operations which tend to its disengagement, it is, however, unlikely that an explosive atmosphere would be created at temperatures below the flashing point of the oil, or even somewhat above that point; and in any case, it is evident that a very moderate amount of ventilation would obviate any risk which might otherwise arise. It is satisfactory to find that in only two cases has the inflammable character of the material led to accident in the marine transport of refined petroleum (kerosene) in bulk. The cases are those of the "Petriana," due to the ignition of spray, and not attended by any audible explosion, and of the "Lux," originating in the ignition of oil in the boiler space.

The conditions under which an explosive mixture of petroleum vapour and air may be ignited, formed the subject of experimental investigation by Colonel Majendie, Dr. Dupré, and the author, in connection with the destruction of the "United." It was found that neither the glowing end of an ordinary wooden match, or of a "fixed star" vesuvian (the flame of which had burned out), nor a red-hot coal (which had ceased to blaze), nor a shower of sparks from a flint and steel, was capable of causing the combustion of the mixture; but a platinum wire raised to a temperature approaching white-heat by means of electricity, invariably caused ignition, though at red-heat no such effect was produced. It was further found that neither the brilliant sparks emitted by the Japanese fireworks known as "scintillettes," nor those discharged from the fireworks termed "golden rain," sufficed to ignite the explosive mixture.

The precise temperature requisite for ignition varies with the chemical composition of the hydrocarbons present in the air, for Victor Meyer has found that a mixture of oxygen and ethane (C_2H_6) will ignite at a lower temperature than a mixture of oxygen and marsh gas (CH_4). In conjunction with A. Münch[1] he has performed a series of experiments which show that the "explosion temperature" of a mixture of a gaseous or vaporised paraffin with enough oxygen for complete combustion, is higher than that for the corresponding olefine, in the case, at any rate, of the lower members of the series. The average temperatures found were as follows:—Ethane, 616° C.; ethylene, 680°; acetylene, 511°; propane, 547°; propylene, 505°; butane, 548°; and butylene, 543°.

In the practical application of these results, it should be borne in mind that while a heated rivet may be at a temperature below that which is requisite for the ignition of a mixture of petroleum vapour and air, its employment in the repairing of a petroleum tank containing such a gaseous mixture may nevertheless be attended with grave risk. In tanks which have been used in the transport or storage of petroleum, there is always a small quantity of the liquid between the plates at the laps, which cannot be removed in the cleansing of the tanks, and the author has frequently seen a flame produced by the ignition of this oil when a heated rivet has been hammered up. A flame may also be produced if a heated rivet is accidentally dropped upon cotton waste or sawdust, especially if the latter are oily. An electric spark causes the ignition of an explosive mixture of petroleum vapour and air, but a mixture containing a very small proportion of hydrocarbon vapour may be ignited by means of a flame when the passage of an electric spark fails to produce active combustion.

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[1] *Berichte d. d. Chem. Gesellschaft*, 1893, xxvi., 2421.

There are several cases on record of the so-called "spontaneous" explosion of benzoline vapour, the majority of which have occurred in connection with the process known as "dry cleaning," in which petroleum spirit is employed as a detergent. It fell to the lot of the author to investigate an instance of an alarming explosion of this character at a leather works, in December, 1890. The explosion took place in a strong wrought-iron tank of about 500 cubic feet capacity, and although not sufficiently violent to cause the bursting of the tank, was attended with a loud report and caused much consternation. It was attributed at the time to some chemical action which had been set up, but the author was enabled to demonstrate that it was due to the discharge of electricity resulting from the friction of the liquid (petroleum spirit) and the other contents of the tank. The subject has recently been investigated by Richter,[1] who finds that the development of electricity by the friction of benzoline occurs with silk and woollen goods (wool becoming positively and benzoline negatively electrified), but not with cotton and linen fabrics; and that at low temperatures the action is more frequent than at higher ones, the electrification taking place very readily at − 15° C., with ease at 0° C., only moderately at + 15° C., and not at all at + 22° C. and upwards.[2] It is not a very uncommon occurrence in petroleum refineries for explosions to occur in the agitators in which the distillate is subjected to agitation with chemical agents, and it is probable that these explosions are traceable to a similar cause. It has further been suggested that spontaneous explosions which have taken place in the industrial employment of ether, carbon disulphide, and petroleum spirit, may in some cases be due to the combustible vapour coming into contact with heated surfaces, the temperature of which may be considerably below the usually accepted point of ignition, owing to the local frictional heating resulting from the passage of a stream of gas under pressure between confining walls.

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[1] *Zeitschrift für angewandte Chemie*, 1893, 218-221.

[2] It has been shown by Dr. Richter, Dr. Schwarz, and others, that the electrical excitation of petroleum spirit may be prevented by the addition of a small percentage of a soap. Soaps made with potash, ammonia, and magnesia, appear to have all been employed with success for the purpose.

An interesting illustration of the manner in which petroleum vapour, when ignited, may carry flame is afforded by the following particulars obtained from an eye-witness by the author while engaged in investigating the circumstances attending the outbreak of fire at a petroleum spirit refinery at Hackney Wick, in December, 1890. Benzoline was being pumped into a horizontal cylindrical boiler-plate still, provided with a 2-inch vent-pipe, through which, as the still was warm at the time, a large quantity of vapour was doubtless escaping. Immediately outside, and over the open doorway, at the west end of the house in which the still was situated, and at a height of about 12 feet from the ground, was a gas-lamp alight. At the east end of the still-house was another open doorway, and as a strong east wind was blowing at the time, the vapour would, of course, be swept from the still towards the lamp over the west doorway. The eye-witness, who was an employé, saw flames playing round the lamp, but before he could take any action, he distinctly observed the flame flash from the lamp to the still, and immediately afterwards the still-house was in a blaze.

From the experience which has been gained, and from the results of the experimental investigations described, valuable deductions may be drawn, not only in respect to the principles of construction of petroleum tank steamships, to which sufficient reference has already been made, but also in regard to the management of such vessels.

Precautions to be observed in the Management of Tank Steamships, the Use of Naked Lights, Smoking, Cleaning Tanks, and Ventilation.—So long as the cargo tanks of a properly-constructed steamer are full of oil, there is very little risk of fire or explosion except through serious structural damage resulting from collision or other accident. The accumulation of vapour in the 'tween-deck bunkers through leakage of oil from the expansion trunks of the oil tanks into those spaces must, however, be guarded against by efficient ventilation, and the height of the oil level in the expansion trunks should be frequently ascertained, with a view to taking the necessary measures to prevent the trunks from becoming over-filled or empty in consequence of increase or decrease of volume of the oil. The coefficient of expansion of petroleum varies according to its chemical composition, but for practical purposes the alteration in volume may be taken as 2 per cent. for 40° F., and this is the smallest amount for which provision should be made.

Even in the case of tank steamships carrying crude petroleum, there would not be sufficient justification for any attempt to prevent smoking and the use of matches *while at sea*, but it is certainly desirable that special places should be set apart for smoking and that only safety matches should be used; both smoking and the use or carrying of matches elsewhere being strictly prohibited.

The chief risk of accident with petroleum tank steamships occurs during the operations of loading and discharging. Accordingly, when a vessel has arrived in port to load or discharge a cargo of petroleum, smoking or the use or carrying of matches of any kind anywhere on board, as well as the employment of naked lights and fires (other than the main boiler fires, which should be banked), should be rigorously prohibited. Both at sea and, especially while in port, it is desirable that the vessel should, except as regards the necessary marine lights, be lighted only by incandescence electric lamps, the ship being carefully wired, the positions of the switch-boards being judiciously chosen, and any lamps used in spaces liable to become charged with vapour being of such construction as not to constitute a source of danger. It is desirable that the tank covers should be kept closed as much as possible during the discharge of the cargo, and in the case of crude petroleum care should be taken that the covers are screwed down tight while loading is in progress and before water ballast is run into any tank which has been emptied of oil, so that the displaced vapour may be discharged through the vapour-pipe.

As the breathing of air charged with a considerable quantity of petroleum vapour quickly produces insensibility, and in view of the danger of explosion, it should be an invariable rule to expel all inflammable vapour from a tank in which any work is to be done, though, if there is urgent necessity for sending a man into an unventilated tank, he may be furnished with a Kleeman respirator, which consists of a light helmet supplied with air through a flexible tube from a small pair of double-action bellows. It need scarcely be said that when repairs necessitating the employment of hot rivets are to be carried out, thorough cleansing and the complete removal of inflammable vapour should first be effected, and this should not be confined to the oil tanks themselves, but should be extended to any ballast tanks, coffer-dams, or other contiguous spaces into which leakage of oil or diffusion of vapour may have occurred.

After filling the empty tanks to overflowing with water to discharge the residual oil, and pumping out the water, it is not unusual to inject steam into the tanks, a treatment which seems to be advantageous. If the vessel is fitted with steam jet or fan ventilating appliances, these should then be put into action, and soon afterwards men may be sent into the tanks to clean them down by hand with a stream of water from the pump, the operation being usually completed by drying the surfaces with sawdust. If there are no arrangements for exhausting the vapour from the tanks, the best must be done with windsails.

When the vessel is in dry-dock, the ventilation of the tanks may be greatly expedited by knocking out a number of rivets at the bottom of the vessel and thus making openings through which the heavy vapour may flow out. It has been suggested that instead of disturbing the rivets, either a manhole or two or three plugholes about 1½ inches in diameter should be formed at the bottom of each oil compartment.

During the prevalence of electrical disturbance, the removal of inflammable vapour from the tanks should be suspended, and when the proportion of vapour in the tanks is believed to be large, care should be taken not to carry on the ventilation while other vessels having lights and fires on board are alongside.

In order to ascertain that ventilation has been carried out efficiently, it is necessary that the atmosphere of the oil tanks and adjacent spaces should be carefully tested for petroleum vapour. In reporting upon the "Tancarville" accident, the Inspectors for the Board of Trade suggested that "when repairs require to be carried out in a vessel which has been carrying petroleum, there should, in our judgment, be a formal handing over of the vessel to those by whom the repairs are to be undertaken, and a certificate given that the tanks and all dangerous spaces have, so far as practicable, been adequately cleansed and ventilated and rendered free from risk of explosion or fire. If from any cause a complete certificate of this sort cannot be given, then it should be clearly notified which tanks or spaces have not been cleansed and are still dangerous." Such certificates have for some years past been issued by the author and his brother, Mr. Robert Redwood, the method now adopted by them in testing being that described in the section relating to the testing of petroleum.

The Transport, Storage, and Distribution of Petroleum in the United Kingdom, &c.—The kerosene imported into Great Britain and Ireland from the United States and Russia *in bulk*, is landed at the ports of London, Liverpool, Barrow, Bristol, Cardiff, Shields, Hull, Plymouth, and Belfast.

In **London**, the principal wharves are at Purfleet, Thames Haven, Millwall, and Silvertown on the Thames, and at Bow and Bethnal Green on the Lea Cut and Regent's Canal respectively. Discharge takes place direct from the tank steamer into the storage tanks at Thames Haven and Purfleet, and by means of a pipe-line, oil is pumped from steamers lying in the Regent's Canal Dock into tanks at Bow. For the landing of the oil at the other wharves named, tank barges are employed, the steamers lying during the discharge, at moorings in the Thames at Charlton and Greenwich. Besides these wharves, at which the storage is principally effected, there are smaller installations at Hammersmith, Battersea, Chalk Farm, Charlton, Greenwich, and Camberwell; and to facilitate the distribution of the oil carried by barges and tank railway wagons, there are many still smaller tank depôts at railway stations and elsewhere. With two exceptions, the larger storage installations are provided with vertical cylindrical iron or steel tanks, placed on the ground, but surrounded with a moat, formed by embankments or walls, of a capacity equal to that of the tanks enclosed. These tanks are usually from about 40 to 70 feet in diameter, by about 25 to 30 feet in height, but in some instances, are as much as 90 feet across. The largest hold about one million imperial gallons, each inch of depth being equivalent to about 3,300 gallons. Some of the tanks have a flat top with a raised edge forming a receptacle for water, and others a slightly domed top. The exceptional cases referred to are those of a wharf at Bethnal Green where the tanks are rectangular and are placed underground, and one of the wharves at Bow, where the tanks are of concrete lined with lead. At the distributing stations on the railways, horizontal cylindrical tanks are employed.

At **Liverpool**, the Mersey Docks and Harbour Board have erected a number of vertical cylindrical tanks, holding from 2,000 to 3,000 tons of oil each, in the neighbourhood of the Herculaneum Dock. The tank steamers discharge in the dock, and the oil is pumped direct into the tanks through an 8-inch pipe-line. At Birkenhead, there are other similar installations adjoining the Great Float Dock where the tank steamers discharge.

In the **Barrow, Hull,** and **Bristol** (Avonmouth) Docks, provision has also been made for the direct discharge into storage tanks.

Comparatively little kerosene is now landed in barrels at the ports already referred to, but barrelled oil is largely shipped to the less important centres of distribution on the coast, especially in the case of Ireland. Oil in barrels is stored in piles either in sheds or in the open air, but if it is not placed in a building, it must be protected from the sun and wind, which would cause drying and shrinking of the barrels, and consequent loss of oil by leakage. In some places, where the soil is sandy, the barrels are buried in trenches if the oil is to be stored for a long time. The barrelled oil stores are surrounded by an embankment or a wall, to prevent outflow in case of fire.

Lubricating oils are imported from the United States in barrels, but from Russia are brought in bulk. The solar oil distillate used by gas companies in the manufacture of carburetted water gas and in the carburetting of coal gas, is also shipped in bulk. Paraffin scale for candle making is transported in barrels, the material being frequently run into the packages in a melted state; and paraffin wax is packed in cases.

Under the regulations made by the Thames Conservancy, petroleum spirit, which is brought into the port of London in barrels from the United States, is landed at Thames Haven, and is stored in concrete warehouses, where it is kept cool and not exposed to currents of air, loss by evaporation being thus minimised. Similar provision for the storage of petroleum spirit in barrels is made at the port of Liverpool, and elsewhere.

The principal ports on the European Continent into which kerosene is imported in bulk, are Antwerp, Rotterdam, Hamburg, Bremen, Amsterdam, and Stettin. At all these, the arrangements for storage are similar to those already described in the case of the larger installations in the United Kingdom. The tank steamships discharge in the docks direct into the storage tanks, unless this is rendered impossible by insufficient depth of water, in which case the vessels are moored in the stream and the oil conveyed from them by tank barges.

The oil imported into Antwerp, Rotterdam, and Amsterdam, is distributed in Belgium and Holland in railway and road tank wagons, and in barrels of wood or steel. Much of the oil landed at the first two of these ports, is conveyed into Germany in tank barges of very considerable capacity, by way of the Scheldt and Maas and the Rhine. From Hamburg, the oil is principally conveyed by tank barges up the Elbe, and stored in distributing depôts at Riesa and elsewhere. From Bremen, the distribution is chiefly effected in railway tank wagons and in barrels.

For the supply of the Eastern markets, kerosene has until recently been shipped only in cases, but it is now also carried in bulk in tank steamships through the Suez Canal, and tank storage installations have been erected in Yokohama, Kobe, Nagasaki, Singapore, Penang, and Bangkok, as well as in some of the Indian ports.

Mr. Carrington has given an account[1] of the methods adopted in this country for receiving, storing, and barrelling refined petroleum for distribution to the retailer. The oil is transferred from the ship to the storage tanks by pumping it through a line of wrought-iron piping of 6 to 8 inches diameter. The pipe-line is preferably laid in straight lengths, with T-pieces instead of curved pieces at the angles, in order to facilitate cleansing, and is tested to about 60 lbs. per square inch. The pipe-line is provided with cocks where air is likely to collect, and is so arranged that it may be emptied on the completion of the discharge of the cargo. The flexible hose which connects the pipe-line with the tanks in the ship, is usually made of a number of layers of prepared canvas, strongly wired both inside and outside, and covered with a tight layer of Manilla cord. Gun-metal flanged connections are fitted to each end.

As the first portion of the cargo discharged is often cloudy, and occasionally mixed with water, the pipe-line is in some cases fitted with a branch, through which such oil may be diverted to a "dirt tank" (Figs. 179 and 180), having a capacity of about 20,000 gallons. After being allowed to settle for a few days, this oil is transferred to the storage tank or barrelled at once.

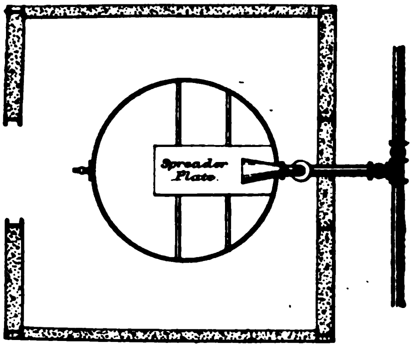

Fig. 179.

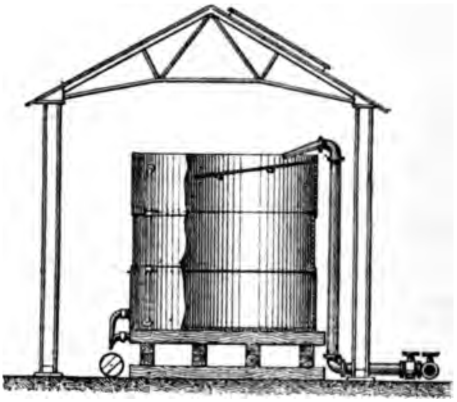

Fig. 180.

The pipe delivering the oil into the storage tanks may pass in through the top to the bottom of the tank as in Fig. 181, or may enter through the side-plates as is shown in the same figure. In the latter case, it is fitted with a swivel joint, so that it may also be used for drawing off, either from near the surface or from any other level. The pipe preferably terminates in a flattened nozzle, for this construction prevents jarring of the tank during filling, and minimises the spraying of the oil. The oil is pumped into the tanks at the rate of from 600 to 1,000 barrels per hour, the pressure in the pipe ranging from 20 to 40 lbs. per inch. The capacity of the tanks varies from 3,000 barrels (120,000 gallons) to upwards of 20,000 barrels (800,000 gallons), the number and size depending upon local circumstances. The bottoms of the tanks are flat, and are formed of the largest possible plates, to minimise the number of seams. On shingly or rocky ground, the foundations are merely formed by levelling, but on marshy sites, various forms of foundation are used. Sometimes the tanks are bedded upon a thick layer of concrete, or upon a timber foundation built upon piles. Mr. Carrington has introduced a foundation of creosoted timber consisting of two layers of baulks arranged crosswise, and covered by timbers on which the tank rests. Another method of procedure, which has been found satisfactory for marshy ground, consists in covering the site with a thick layer of brushwood, on which is laid, first about 18 inches of well-rammed chalk, and then from 6 to 8 inches of clean ballast. Sufficient ventilation is obtained by the use of windsails in the manholes, to allow of men entering and cleaning out the tanks a few hours after the removal of the oil.

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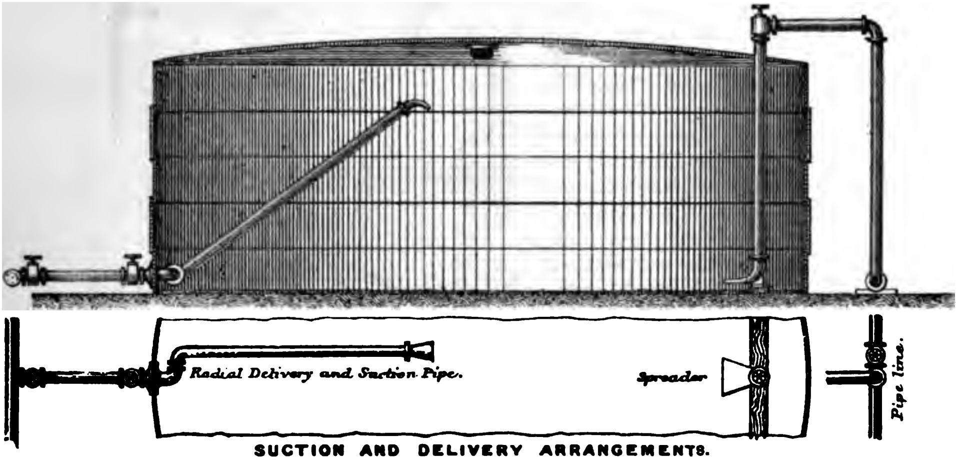
[1] *Minutes of Proc. Inst. Civ. Engineers*, cv.

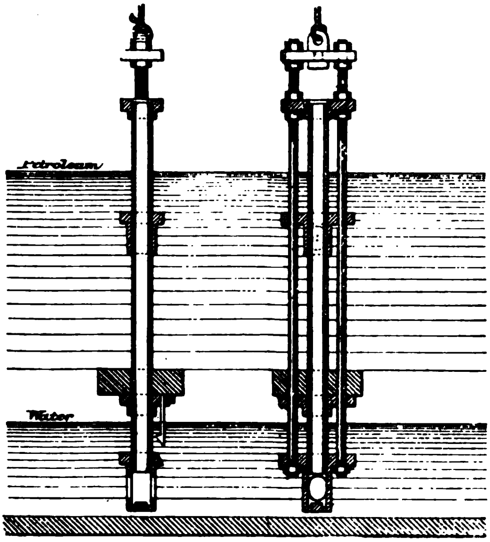


SUCTION AND DELIVERY ARRANGEMENTS.

Fig. 181.

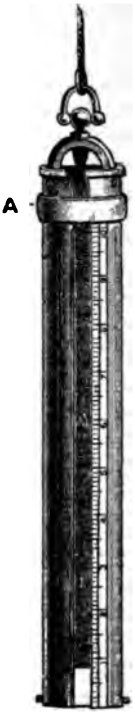
The depth of oil is usually ascertained by means of a sounding apparatus, introduced by the author and his brother. This consists of a suitably loaded steel tape on which, at about the level of the oil, an ebony plate is clipped. As the oil level is very clearly defined on the surface of the ebony indicator, accurate measurements can thus be taken; and the appliances possess other obvious advantages over the rigid sounding rod previously employed.

To ascertain the presence and amount of water in a tank containing oil, the water-finder and gauge patented by Messrs. Horley & Sedgley has been used. The instrument consists of a glass tube fixed in a frame, and provided with a sliding cap by means of which the lower end can be closed. When the apparatus is lowered into the liquid, the tube is open at both ends, but on the sliding cap coming into contact with the bottom of the tank, the frame, which is weighted, descends; the tube is thus closed at the bottom, and a sample of the liquid or liquids enclosed. In Fig. 182, the tube is shown open for the entrance of the sample.



WATER-FINDER AND GAUGE.

Fig. 182.



REGISTERING WATER-FINDER.

Fig. 183.

Fig. 183 represents a registering water-finder introduced by the author in conjunction with Mr. Robert Redwood and Mr. Herbert Barringer,[1] and now in general use. It depends for its action upon the change effected by water on the surface of a chemically-prepared paper which is unacted upon by oil, and consists of a weighted hollow brass cylinder provided with a convenient means of suspension in a vertical position, and with a sliding brass collar which fits tightly when in the position shown. This collar holds in position a strip of the prepared paper, which lies in two longitudinal grooves cut on opposite sides of the cylinder. At the side of each groove, a scale, divided into inches and tenths, is engraved on the cylinder. The apparatus is lowered into the tank by a cord, and when it touches the bottom, is allowed to remain in a vertical position for a sufficient length of time for the water to act upon the prepared surface—usually about thirty seconds. On withdrawing the instrument, the depth of the water is found indicated on the paper on both sides. The illustration exhibits the appearance of the apparatus after use, the paper registering a depth of eight-tenths of an inch of water.

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[1] See *Industries*, Jan. 20, 1893, 49.

It is important to have a means of accurately determining the quantity of water present, for it is the invariable practice to ascertain the outturn of each cargo by measuring the depth of the contents of the storage tanks when the discharge has been completed, the volume being converted into weight by calculation, on the basis of the specific gravity of the oil, and it is therefore necessary to know what depth of water is to be deducted from the total depth of liquid.

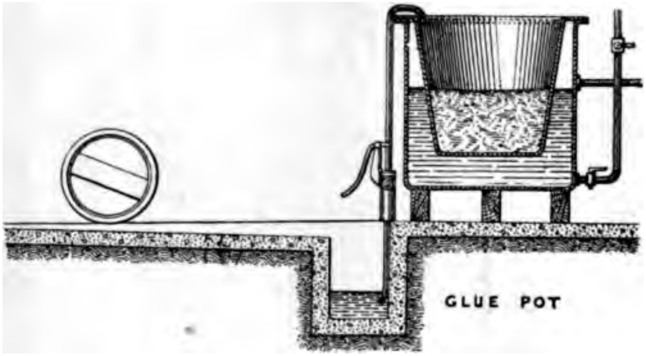
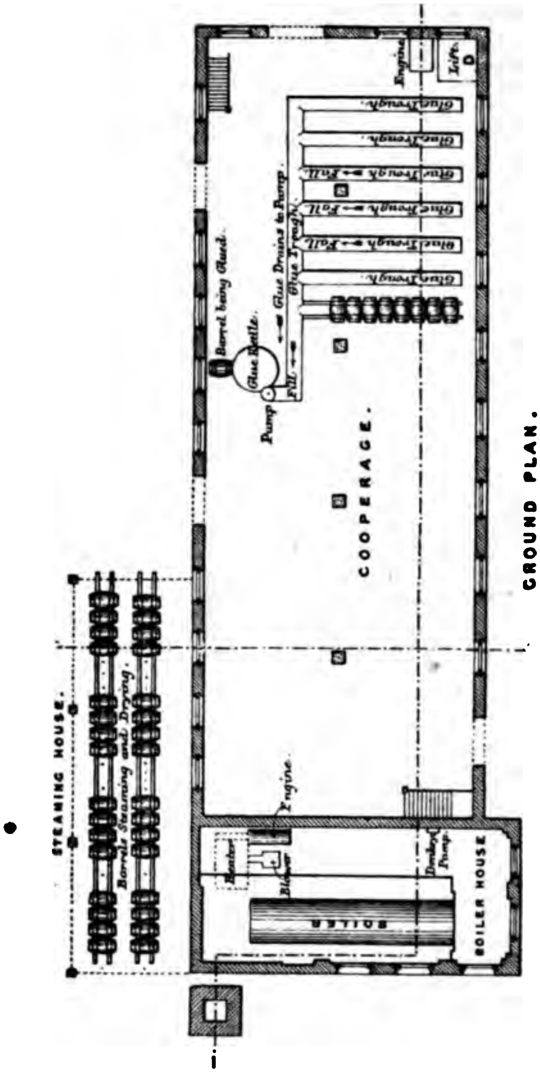


Fig. 184.

For distribution, the oil flows or is pumped through a pipe from 4 to 6 inches in diameter, into tank barges, or into a filling tank, and thence through a smaller pipe into tank railway wagons, tank road wagons, or barrels. The tank barges are of iron or steel, or of wood with independent iron or steel tanks, and are often of large capacity. The distribution of oil in bulk has led to the very general use of such barges on rivers and canals. In some ports—that of London, for instance—tank steamers cannot approach certain of the wharves at which kerosene is stored, and in such cases, as already stated, the oil is conveyed from the steamer to the wharf in tank barges.

The road wagons now largely employed by the principal distributing companies for conveying the oil in bulk to the retailers in this country, are fitted with horizontal cylindrical tanks, which are made of steel, and are commonly 3½ feet in diameter by 8 feet in length. The empty barrels received at the depôt for refilling are examined, and those which require repair are sent to the coopering department. Here they are, if necessary, steamed out, and re-coated inside with a weak solution of glue, which is kept hot by steam in a jacketed pan (Fig. 184). Each barrel is charged with about a quart of the liquid through a siphon-pipe, and after the bunghole has been closed, is rolled about by the workman so that the whole is covered. The barrel is then struck near the bunghole, which causes the bung to be blown out by the



GROUND PLAN.
Fig. 185.

steam inside, and is placed in such a position that the surplus glue may drain out into a zinc-lined trough. The barrels are next placed for some time in a drying-room, and are finally re-painted and weighed, the tare being marked upon each.

The barrel-cleaning, glueing, and drying arrangements employed at a petroleum storage installation at Avonmouth, are shown in Figs. 185 to 187.[1] At the end of the boiler-house is a large air-heating chamber (Fig. 187) containing a coil of steam pipes. The chamber communicates with a blower by a pipe, A A, and with the main air pipe by pipes, B. From the main air pipe, three branches lead to three pipes, from which are taken short branches, E, of inch pipe arranged about 2 feet apart, and so spaced as to enter the bungholes of the barrels, which are placed over them in three nests of eight barrels each. Valves, G, permit of shutting off connection with any or all of the nests of barrels. Similarly, steam from the boiler passes through a pipe, H, into a main, O, from which it passes into branches, P, leading into the branches of the main air pipe. The barrels are first steamed for ten or fifteen minutes, after which the steam is shut off at Q; the hot-air valve, F, and the branch valves, are then opened, and the barrels are dried with hot air.

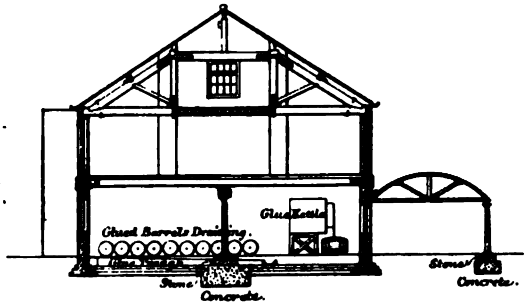


Fig. 186.

The arrangements for coating the barrels with glue are shown in Figs. 185 and 186. After draining, the barrels are lifted to the floor above by a lift, D, to be painted.

The filling tank in connection with the barrelling house is placed at an altitude of 8 or 10 feet, and the oil flows from it into the barrels through a pipe arranged about 30 inches above the ground, and having branches 7 feet apart fitted with flexible hose and automatic cocks, so that a number of barrels can be filled simultaneously (see Fig 188). As soon as the barrel is sufficiently charged—space being left for expansion of the oil—the supply is automatically cut off; the barrel is then bunged, and replaced by an empty one. Fig. 188*a* represents the automatic cock introduced by the Standard Oil Company. It is fitted with a float which, as shown, releases a catch when the oil reaches a certain level, and allows a valve to close.

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[1] Pickwell, *Min. of Proc. Inst. Civ. Engineers*, 1891, civ., 234.

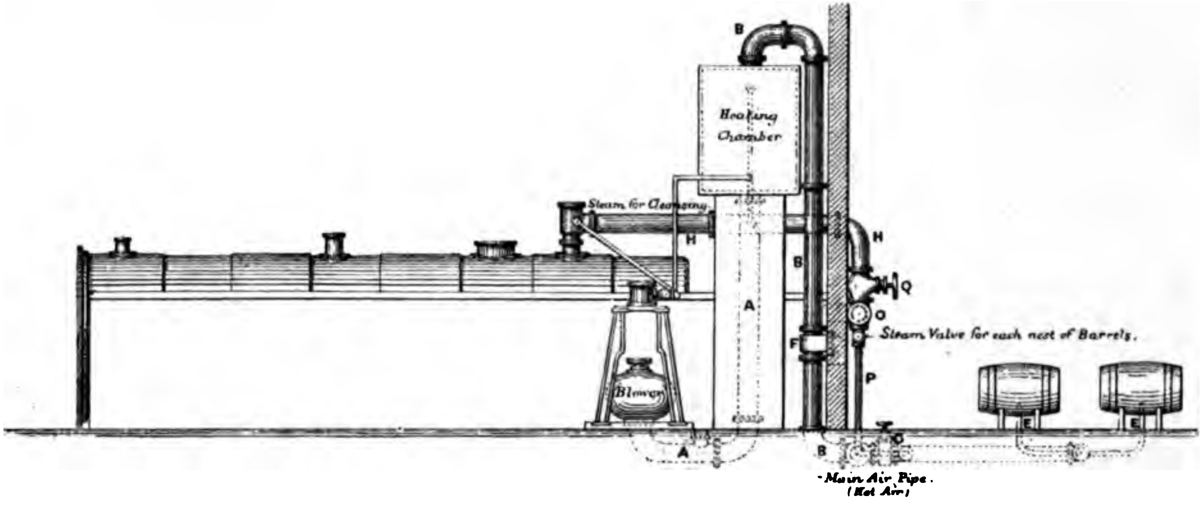
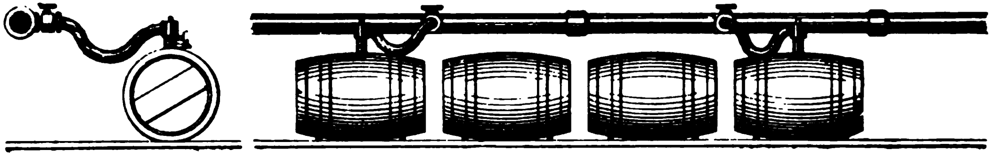


Fig. 187.

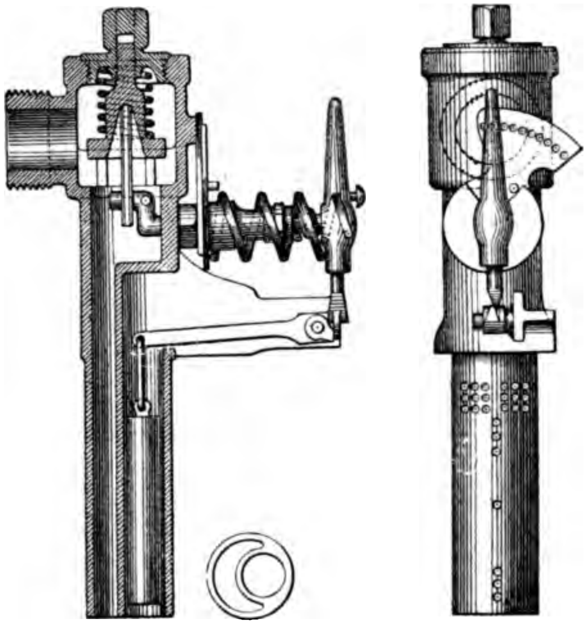


FILLING ARRANGEMENT.

Fig. 188.

A steel barrel has been introduced by the Société Anonyme de Ronet, of Namur. It is formed in two sections, each of which is made from a flat steel plate by heavy pressure. The two sections are joined by pressure, the flanged edges being so formed as to interlock. Such a barrel, of a capacity of 44 gallons, is stated to weigh about 70 lbs.

The steel barrels manufactured under the patents of Barraclough and Heaton are of the same shape and externally of the same size as the wooden barrels now in use, but are capable of containing 50 gallons of oil. The bodies are made from rectangular sheets, with a single longitudinal joint welded by an electrical process. The ends are of stamped steel, and are fixed between an outer and an inner steel hoop. A screw-plug is fitted to the body and to one end.



AUTOMATIC FILLING COCK.

Fig. 188*a*.

Caird's patent steel barrels are stamped cold out of sheet steel, of a suitable thickness, according to the size and strength required. They are made without longitudinal seams, and are strongly jointed circumferentially by spinning the edges of the two shells together and locking them in such a manner that it is impossible for them to become disjointed. At the same time, the increased thickness of metal at the joint adds greatly to the strength of the barrel at the point where it is most liable to shock or strain. The smaller barrels have one joint only, made on the outside, but below the bilge. The larger are made with three joints, two being on the inside, forming a circumferential T rib, the middle joint being formed as in the smaller barrels. The weight of the 40-gallon steel barrel is stated not to exceed that of a wood barrel of equal capacity. The steel barrels are of the same shape as wood barrels, and are of uniform capacity and weight. There are two methods of closing the barrels. The bung and vent holes may be stamped out so as to leave a short neck inside the barrel, so that ordinary wooden shives can be used, or at a small extra cost, a screwed ring and cap for the bung hole and a screwed vent, can be fitted.

The Anglo-American Oil Company have introduced a very convenient form of storage tank for kerosene for domestic use. It is fitted with a small pump, by means of which an oil can or even the lamp reservoir itself is easily filled without risk of spilling the oil, and is provided with a hinged cover to exclude dust.

SECTION IX.

THE TESTING OF CRUDE PETROLEUM, PETROLEUM AND SHALE OIL PRODUCTS, OZOKERITE AND ASPHALT.

A LARGE number of physical and chemical tests are applied to the raw material and manufactured products to which this work relates. The industry is conducted upon a basis of recognised standards of quality, and testing is necessary on the one hand to satisfy the refiner that his processes are being properly conducted, and on the other to protect the buyer. Moreover, certain products are required to conform to statutory and municipal regulations, and prescribed tests have to be applied in connection with these restrictions.

Crude Petroleum.—The density of crude petroleum, and the amount of water and earthy matter in suspension, are usually ascertained. In many cases, a test of fractional distillation is applied with a view of detecting any admixture of distilled products or residue. In Burma, the flashing point is frequently determined in connection with regulations relating to the transport. It may also be requisite, in the case of a crude oil from a new district, to take note of the colour and odour, to determine the flashing point, the viscosity, whether separation of solid hydrocarbons takes place on cooling, and if so at what temperature, and whether sulphur is present, and if so in what proportion; also to ascertain experimentally what percentage of the usual commercial products, oil similar to the sample may be expected to yield on the manufacturing scale. In rare instances, it may be desirable to determine the elementary composition of an oil and its calorific value.

Petroleum Spirit and Shale Spirit.—In the case of petroleum spirit or naphtha, including benzine, gasoline, &c., the specific gravity and range of boiling points are the most important characters, but the fractional distillation test is also sometimes applied. Deodorised American petroleum spirit should leave no unpleasant odour when it is evaporated on the hand, and when it is to be employed as a substitute for oil of turpentine in paints, it is important that it should contain no sulphur compounds. Shale spirit is similarly tested.

Kerosene and Paraffin Oil.—The colour, odour, flashing point or fire test, and specific gravity of kerosene and paraffin oil (from shale) are in most cases the only characters to be determined for contract purposes, and of these, usually only the flashing point or fire test is taken cognisance of in legal enactments. The oil is, however, occasionally examined as to its "burning quality," its "capillary power," its composition (as ascertained by fractional distillation), its acidity or alkalinity, its freedom from "soaps," its freedom from sulphur compounds, and the amount of ash which it yields.

Lighthouse Oil.—The Trinity-house contract conditions for mineral oil intended for use in lighthouse lamps specify that—

1. The mineral oil required to be supplied under this contract is to be of the best possible quality, the greatest care is to be taken in its preparation, and it must be perfectly free from sulphuric acid.
2. In all cases, whether the oil be petroleum or paraffin, its flashing-point is to be determined by using the apparatus described in Schedule 1 of the Petroleum Act of 1879.
3. If the oil be petroleum, its flashing-point is to be not lower than 125° F. (close test), and it is to distil between 302° and 572° F., the temperature of the vapour, not that of the liquid, being taken.
4. If the oil be paraffin, its specific gravity is to be not less than 0·810, nor greater than 0·820, at 60° F.; its flashing-point is to be not lower than 140° F. (close test), and it is to distil between 302° and 572° F., the temperature of the vapour, not that of the liquid, being taken.
5. The illuminating power of the oil supplied, whether petroleum or paraffin, is to be equal to that of the best colza oil when consumed in a Trinity-house Argand lamp.

For the distillation test, about 250 grammes of the oil may be taken, the operation being conducted in an ordinary distillation flask with the bulb of the thermometer midway between the shoulder of the flask and the lateral tube leading to the condenser. The upper part of the flask should be wrapped in asbestos cloth.

The United States Lighthouse establishment stipulates that mineral oil supplied for use in lighthouse lamps shall have a specific gravity "not less than 0·802," a flashing-point of not less than 140° F., and a fire test of not less than 154° F., both these tests being made with Tagliabue's instrument. The oil is to remain limpid at zero; and "litmus paper immersed in it for five hours must remain unchanged." The oil is to be photometrically tested in a fifth-order Hains lamp, and the light is to be equal to that of eighteen sperm candles, and to continue undiminished during five hours' burning.

Mineral Colza (or Sperm) Oil.—The colour, specific gravity, and flashing point of this oil are commonly ascertained.

Solar Oil Distillate.—The specific gravity and flashing point of this product are usually determined, and in some instances the oil is subjected to fractional distillation in order to ascertain whether it is a "natural distillate," as distinguished from an "artificial" mixture of distillates.

Lubricating Oils.—The principal characters to be determined in respect to lubricating oils are the colour (in the case of "pale" oils), the odour, the viscosity, the flashing point, the "cold test," and the specific gravity. In some cases, the loss by volatilisation on exposure to an elevated temperature is also ascertained. Lubricating oils should be free from acid and alkali, and should not have any empyreumatic odour. The viscosity of "pale" machinery oils is usually determined in this country at the temperatures of 70° F. and 140° F., and of "cylinder" oils at 200° and 250° F. The extent of reduction in viscosity on an elevation of temperature, is a point of practical importance; hence it is the practice to make the test at two temperatures. The cold test of "pale" machinery oil is usually the point at which separation of solid hydrocarbons commences on a gradual reduction of temperature; and of "black" oils, the point at which the oil ceases to flow when slowly cooled. "Compound" oils, or mixtures of mineral oils with fixed oils, are largely employed for lubricating purposes, and it is frequently necessary to determine the proportions in which these oils are present. "Cylinder" oils—*i.e.*, oils for the internal lubrication of steam engine cylinders—should not contain fixed oils, as the latter are decomposed by high-pressure steam, and soaps are formed by the action of the liberated fatty acids upon the metallic surfaces. Black oils should be free from solid matter in suspension. Occasionally, the chemist is called upon to determine whether resin oil is present, or whether any agent has been added to impart "artificial" viscosity. In Italy, there is a differential duty on mineral oils, and a fractional distillation test is applied to lubricating oils to determine whether more than the maximum of 10 per cent. of distillate is obtained below 310° C. The operation is conducted with 20 grammes of the oil in an ordinary distillation flask, with the bulb of the thermometer just below the vapour tube.

Paraffin.—The testing of paraffin is usually confined to the determination of the "melting point" (setting point) and the percentage of oil, water, and dirt present.

Petroleum Residuum.—In the case of American petroleum residuum, it is usual to ascertain the density, the flashing point, and the freedom from water and coke or other solid matter. In the case of Russian petroleum residuum (astatki) intended for use as fuel, the flashing point is the most important character to be determined, but in addition, the specific gravity and freedom from water and solid matter may have to be ascertained.

Vaseline.—The tests which are occasionally applied to this product are chemical rather than physical.

Crude Shale Oil.—In the testing of crude shale oil, it is often sufficient to make a fractional distillation of a portion, and determine the densities of each fraction of 5 per cent. and the setting point of the less volatile.

Ozokerite.—The commercial analysis of crude ozokerite has for its object the determination of the percentage of refined ozokerite which the sample is capable of yielding.

Asphalt.—The examination of asphalt is usually confined to the determination of its physical characters at different temperatures, and its solubility in carbon bisulphide or other solvent.

The various tests to which reference has been made in these introductory remarks, and other chemical tests, will be found fully described in the following pages.

CRUDE PETROLEUM.

Ordinary crude petroleum is required, in the United States, to conform to the following rule of the New York Produce Exchange, except as regards density, the rule having been relaxed in that particular in consequence of much of the crude petroleum now obtained having a greater density than 43° B.:—

"Crude petroleum shall be understood to be pure natural oil, neither steamed nor treated, free from water, sediment, or any adulteration, of the gravity of 43° to 48° B." (0·809 to 0·786 sp. gr.).

In order to determine whether the petroleum is a "pure natural oil," a sample is subjected to fractional distillation, each fraction being one-tenth of the crude oil by volume, and the density of the several distillates is determined. The following results, obtained in the examination of two typical samples, indicate the form of the certificate handed to the buyer:—

Oil from Parker District.	Gravity 46° Baumé.	Oil from Parker District.	Gravity 46° Baumé.
1st Product,	72° B.	6th Product,	46° B.
2nd ,,	62° B.	7th ,,	42° B.
3rd ,,	57° B.	8th ,,	41° B.
4th ,,	53° B.	9th ,,	42° B.
5th ,,	49° B.		

Oil from Bradford District.	Gravity 43° Baumé.	Oil from Bradford District.	Gravity 43° Baumé.
1st Product,	71° B.	6th Product,	41° B.
2nd ,,	60° B.	7th ,,	40° B.
3rd ,,	54° B.	8th ,,	41° B.
4th ,,	49° B.	9th ,,	42° B.
5th ,,	45° B.		

The regular gradation in the densities of the fractions exhibited in the foregoing certificates, is taken to be a satisfactory indication that the oil is a natural product.

The natural lubricating oils (crude petroleums) of Pennsylvania, Ohio, West Virginia, and Kentucky, are classified by the West Virginia Transportation Company according to density, and are subjected to the following test:—

"In receiving and making delivery of oils shipped by the company, the water and sediment contained therein shall be determined by mixing an average sample with an equal quantity of benzine, and subjecting the mixture to 120° F. in a graduated glass vessel for not less than six hours, after which the mixture cools and settles not less than two hours for light grades, three hours for A grade, four hours for B grade, six hours for C grade, eight hours for D grade, and eighteen hours for heavier grades."

The author finds that in the case of the more viscous oils, a larger proportion of benzine, which should always be previously saturated with water, may be used with advantage.

The grades are as follows:—

A. 37·1° Baumé (about 0·840 sp. gr.) and lighter.
B. 33° to 37° B. (0·860 to 0·840 sp. gr.).
C. 31·6° to 32·9° B. (0·868 to 0·860 sp. gr.).
D. 30·6° to 31·5° B. (0·873 to 0·868 sp. gr.).
E. 29·6° to 30·5° B. (0·878 to 0·873 sp. gr.).
F. 28·6° to 29·5° B. (0·884 to 0·878 sp. gr.).
G. 28·5° B. (0·884 sp. gr.) and heavier.

Determination of the Specific Gravity of Crude Petroleum and Petroleum Products.—The specific gravity is usually determined in the trade by means of the *hydrometer*, but the use of a *specific gravity bottle* is, in the opinion of the author, distinctly preferable. In the case of oils imported in bulk, where the weight delivered is calculated from the volume at the observed temperature, it is essential that the specific gravity should be accurately determined, and for this purpose the bottle should always be employed. The *Westphal balance* has been recommended as a desirable substitute for the hydrometer, but the author is unable to endorse this. In taking the densities of viscous oils, he has found that remarkably exact and trustworthy results may be obtained with a *Sprengel tube.* Allen[1] recommends the following method for the thicker and semi-solid oils. Fill a specific gravity bottle to the brim with the warm oil, and when it has cooled to a temperature of 60° F. insert the stopper by working it to and fro until it is forced home, the excess of oil gradually escaping through the perforation in the stopper, then wipe the bottle, and weigh it. It is frequently convenient to determine the density of viscous or semi-solid crude petroleum or lubricating oils at comparatively high temperatures and deduce the specific gravity at the standard temperature from the result thus obtained, on the basis of the known coefficient of expansion of the particular class of oil under examination. Full particulars of the coefficients of expansion of various oils are given in the section relating to the physical and chemical properties of petroleum.

TABLE LIX.—BAUMÉ AND SPECIFIC GRAVITY EQUIVALENTS.

Baumé.	Sp. gr.	Baumé.	Sp. gr.	Baumé.	Sp. gr.
10,	1·0000	37,	0·8395	64,	0·7243
11,	0·9930	38,	0·8346	65,	0·7205
12,	0·9861	39,	0·8299	66,	0·7168
13,	0·9791	40,	0·8251	67,	0·7133
14,	0·9722	41,	0·8204	68,	0·7097
15,	0·9658	42,	0·8157	69,	0·7061
16,	0·9594	43,	0·8110	70,	0·7025
17,	0·9530	44,	0·8063	71,	0·6990
18,	0·9466	45,	0·8017	72,	0·6956
19,	0·9402	46,	0·7971	73,	0·6923
20,	0·9339	47,	0·7927	74,	0·6889
21,	0·9280	48,	0·7883	75,	0·6856
22,	0·9222	49,	0·7838	76,	0·6823
23,	0·9163	50,	0·7794	77,	0·6789
24,	0·9105	51,	0·7752	78,	0·6756
25,	0·9047	52,	0·7711	79,	0·6722
26,	0·8989	53,	0·7670	80,	0·6689
27,	0·8930	54,	0·7628	81,	0·6656
28,	0·8872	55,	0·7587	82,	0·6619
29,	0·8814	56,	0·7546	83,	0·6583
30,	0 8755	57,	0·7508	84,	0·6547
31,	0·8702	58,	0·7470	85,	0·6511
32,	0·8650	59,	0·7432	86,	0·6481
33,	0·8597	60,	0·7394	87,	0·6451
34,	0·8544	61,	0·7357	88,	0·6422
35,	0·8492	62,	0·7319	89,	0·6392
36,	0·8443	63,	0·7281	90,	0·6363

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[1] *Commercial Organic Analysis*, 2nd ed., ii.

In the United States, the density, in relation to *quality*, is usually taken with a hydrometer graduated in degrees Baumé, and the preceding table giving the corresponding specific gravities is in use.

In ascertaining the density for the purpose of calculating the weight from the number of gallons of oil transferred from a tank, a hydrometer directly indicating specific gravity is employed in the United States. The scale of the instrument is an open one (·800 to ·805 = 1¼ in.), and each division represents ·0005. Tables have been prepared for the conversion of gauge into weight, based on the weight of an American gallon of distilled water at 60° F., which, in consultation with the author, was for this purpose taken as 8·331 lbs. avoirdupois.

The Fractional Distillation Test for Crude Petroleum.—The test prescribed by the New York Produce Exchange, to which reference has been made, may be readily carried out with a small still and condenser, or with any other simple form of distilling apparatus. On the other hand, the determination in the laboratory of the proportions of the various commercial products which a hitherto unknown description of crude petroleum may be expected to yield in practice, is an operation not free from difficulty, and demanding some experience for its successful performance, especially if the quantity available for examination is small, as is often the case. The author is accustomed to conduct the process in a glass retort, or an ordinary distillation flask, embedded in sand, heat being applied by means of Bunsen burners of various sizes, and the temperatures above the range of the mercurial thermometer being taken with a Baly & Chorley potassium-sodium thermometer. The distillate is collected in fractions of one-tenth or less, the density of each fraction, and the behaviour of the less volatile of them on exposure to a low temperature, are noted, and these results, together with the temperatures within which the fractions distilled, are compared with data obtained, under identical conditions, with typical samples of crude petroleum of known commercial character. Some judgment is required in the interpretation of the results, because in practice, on the one hand, the process of "cracking," especially as conducted in the United States, results in the conversion into kerosene of much of the intermediate oil obtained in the ordinary laboratory process of distillation; and, on the other hand, owing to the use of superheated steam, there is far less dissociation in the distillation of the lubricating oil fractions. With a view of preventing this dissociation, the author has in some cases found it advantageous to effect the fractionation of the hydrocarbons of higher boiling point in a vacuum.

The Dephlegmator.—Except in the fractional distillation of the most volatile hydrocarbons, the author prefers to work without a dephlegmator. This appliance is, however, largely used. It is made in various forms, but the principle is substantially the same in all. It is well known that when a mixture of two liquids of different boiling points is distilled, the distillate at any stage of the process will be found to contain both liquids, the more volatile predominating in the earlier stages and the less volatile in the later stages, but no complete separation being thus effected. The function of the dephlegmator is partly that of a fractional condenser, and partly that of a "scrubber," the less volatile liquid being condensed and returned to the distilling vessel, and the apparatus being so constructed that the vapour is exposed to a portion of this condensed liquid, with the result that the more readily condensable constituents are washed out of it. In this way a better separation can be effected than is possible in the use of an ordinary distillation flask, but the employment of a dephlegmator in the fractionation of hydrocarbons of comparatively high boiling point is attended with difficulty, and, according to the author's experience, appears often to interfere with the attainment of concordant results.

Linnemann's dephlegmator (Fig. 189) is fitted with several baskets of platinum gauze, of the form shown in Fig. 190, a larger number being used for liquids boiling below 150° C., than for those boiling at higher temperatures. *Le Bel's* arrangement (Fig. 191) is similar. The more readily condensable portion of the vapour is condensed, and the liquid collects in the gauze baskets more rapidly than it can run through into the flask to which the apparatus is fitted; the vapour passing through the dephlegmator is thus brought into contact with the condensed liquid, and only the most volatile constituents pass into the condenser. The dephlegmator is surrounded by a jacket to prevent too rapid cooling, when the fractions of higher boiling point are being distilled. As the accumulation of liquid in the gauze baskets necessitates the periodical removal of the source of heat, so that the liquid may return to the distillation flask, the apparatus of *Henninger* (Fig. 192) is preferable. It has the gauze baskets at the constrictions of two or more bulbs blown in it, but has also side tubes which convey the liquid, as it accumulates, from bulb to bulb downwards, and finally into the flask. In *Glynsky's* dephlegmator, hollow glass balls are substituted for the wire-gauze baskets.

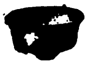

Fig. 190.

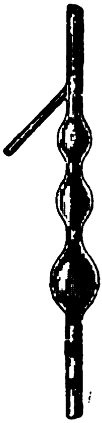

Fig. 189.

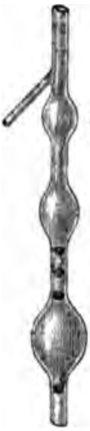

Fig. 191.

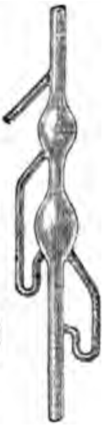

Fig. 192.

Professor Engler's System of Distillation.—For the fractional distillation of petroleum, Engler employs a globular flask (Fig. 193) 6½ cm. in diameter, with a cylindrical neck 1·6 cm. in internal diameter and 15 cm. in length, from the side of which a vapour tube 10 cm. in length extends at an angle of 75° downwards, to the condenser. The junction of the vapour tube with the neck of the flask should be 9 cm. above the surface of the oil when the flask contains its charge of 100 c.c. of oil. The observance of the prescribed dimensions is considered essential to the attainment of uniformity of results. A thermometer is fixed in the cork inserted in the mouth of the flask so that the top of the bulb is on a level with the vapour tube. 100 c.c. of the oil is introduced into the flask by the aid of a pipette, and heat is applied by means of a Bunsen burner. At first, wire gauze is interposed between the burner and the flask, but afterwards the naked flame is employed, the heat being so regulated that from 2 to 2½ c.c. of distillate passes over per minute. In this way, fractions differing from each other in boiling point by 50°, 25°, or 20° C. can be obtained. As soon as the requisite temperature (150° C. for the first fraction) is attained, the lamp is withdrawn until the temperature has fallen at least 20°, when the oil is re-heated to the boiling point and again cooled, this process being repeated until no more distillate is obtained. The oil is then heated up to the next boiling point, and the cooling and re-heating process repeated, and so on with the other fractions. These precautions must be observed in order to produce reliable results, which (it is claimed) can be obtained with not more than a variation of 1 per cent. by this method, even in the hands of different experimenters.

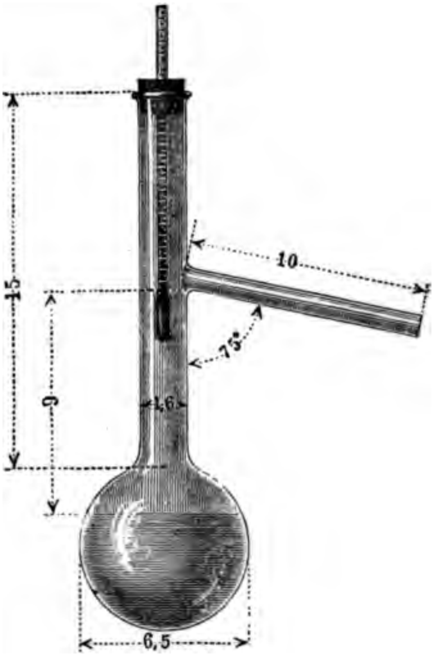

Fig. 193.

In a recent personal communication addressed to the author with reference to this process, Dr. Engler says :—

> "We estimate the proportion of burning oil from the amount of the fractions between 150° and 300° C. in the case of oils consisting of hydrocarbons of the methane series (C_nH_{2n+2}), such as those from Pennsylvania, Galicia, Alsace, &c., or from the proportion of the fractions between 150° and 285° where the hydrocarbons belong to the naphthene series, as is the case with the Baku, Java, and (partially) the Burmese oils. As in practice, some of the fractions below and exceeding the foregoing limits are included as burning oil, the proportion obtained on a manufacturing scale is greater than that yielded by a test sample, but these limits give the nearest indication of the proportion of burning oil. A universal standard

cannot, however, be established, because in some oils, and notably those from Baku, the fraction between 285° and 300° is so heavy as to prejudicially affect its capillary properties with regard to the lamp wick. On the other hand, the same fraction in the American oils can be used for burning without seriously affecting the burning quality. We find inferior American oils contain as much as 15 per cent. by volume of fractions boiling below 150°, and 25 per cent. (volume) boiling over 300°, so these should be considered as the extreme limits.

"If it is only a question of determining the amount of spirit, burning oil, &c., identical apparatus and method of working are, in my opinion, of greater importance than the complete separation of the single fractions. My apparatus, now very generally used in Germany, was designed with this object, and I discarded a dephlegmator as giving less regular results than a simple instrument, in the hands of different experimenters. By carefully following the directions, the margin of error is only about ¼ to ½ per cent. At present we fractionate in stages of 25°; for instance, the benzine fraction boiling at, say, 86°, would be included in the fraction boiling at 100°, and the subsequent fractions are taken at every 25° (100° to 125°, 125° to 150°, 150° to 175°, . . . 275° to 300°). By adding together the fractions up to 150°, the quantity of light spirit is ascertained; the burning oil comprising those between 150° and 300°, and so on. The former practice of taking fractions at every 20° is discontinued. However, in estimating the actual component parts of an oil, smaller fractions are necessary. In the burning oil, the greater the proportion of the first fraction above 150° the better, the converse being true in the case of the fraction above 250°."

Regnault's Distilling Apparatus.—In France, the Regnault instrument is employed in fractional distillation. It consists of a copper retort, *A* (Fig. 194), having a bent side tube, *b*, passing into a metallic condenser, *B*, which terminates, both above and below, in narrow tubes, *g* and *i*. The condenser is fitted into a cylinder, *f*, containing water, which is supplied through a pipe, *o*, *n*, and discharged at *p*. The whole is supported by a tripod, *P*, having a ledge, *h*, *l*, upon which is placed a box, *V*, containing graduated glasses for receiving the distillates, five in number, and graduated in cubic centimetres. Each of the glasses, 1, 2, 3, 4, 5, can be brought under the outflow tube, *i*, of the condenser. 100 cubic centimetres of the oil is introduced into the distilling vessel (which should not be more than one-third full) through the neck, *a*. Through the cork closing the neck, is passed a thermometer, *T*, the bulb of which should not dip into the liquid, but should be just below the tube leading to the condenser. Heat is applied by means of a gas or spirit lamp, *S*. The oils contained in the crude petroleum may be fractionised into those—

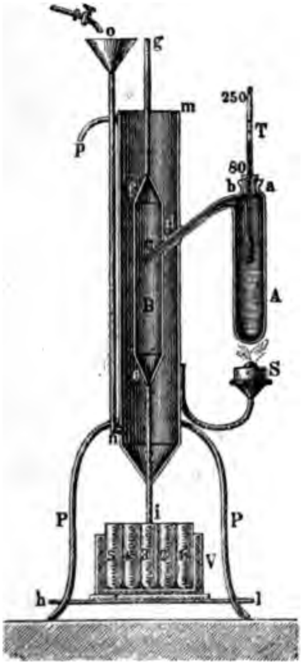

Fig. 194.

Distilling below 150° C.
" between 150° and 180° C.
" " 180° and 210° C.
" " 210° and 240° C.
" " 240° and 270° C.

The receiving glass No. 1 is used to collect the first portion of distillate, No. 2 being substituted when the temperature rises above 150°, No. 3 when 180° is passed, and so on, No. 5 receiving the final fraction, obtained between 240° and 270° C. The volume of distillate in each glass is taken as representing the weight of the fraction in the original oil. This, though not exact, owing to the variation in the relation between specific gravity and volume in different fractions, is considered to be sufficiently correct for technical purposes.

Other Forms of Distilling Apparatus.—Professor Peckham[1] recommends the use of an *alembic* in preference to a glass retort for the fractional distillation of crude petroleum in the laboratory, as the cracking of the oil is largely prevented. An apparatus devised for the purpose by Dr. Letheby, is described in the *Journal of Gas Lighting*, xii., 653; another form, proposed by Dr. Attfield, in the *Chemical News*, xiv., 98; and a third, invented by Peckham for the technical analysis of petroleums or solid bitumens by distillation, either with or without pressure, in the *American Journal of Science and Arts*, xliv., 230, and in the *Chemical News*, xvi., 199.

Determination of the Calorific Value of Crude Petroleum or Petroleum Residuum.—The elementary composition of crude petroleum (which is determined similarly to that of other organic bodies) does not necessarily indicate with precision the thermal efficiency of the oil, for the heat of combustion is dependant upon the state of combination of the elements in the sample, and this may vary without affecting the percentage composition; in the case of crude petroleum or petroleum residuum intended for use as liquid fuel, a direct calorimetric test is therefore desirable. At the request of the author, Mr. William Macnab has made experiments with typical samples of crude petroleum which have satisfied him that the instrument known as the *calorimetric bomb* is well suited for use in the determination of the thermal efficiency of petroleum. The process consists in burning the sample in a closed bomb in presence of excess of oxygen, the bomb being immersed in a calorimeter which is properly protected from loss or gain of heat by a suitable envelope. The water in the calorimeter is continually stirred during the progress of the experiment, and readings are taken with a cathetometer on delicate thermometers which indicate to $\frac{1}{200}$° C. Of course the value in water of the whole system is accurately known, and as all the products of combustion are retained in the bomb during the experiment, all the heat generated must be communicated to the water. Owing to the protection afforded to the calorimeter, and the means of reading, with precision, minute differences of temperature, extremely accurate and concordant measurements can be made. The necessary oxygen is introduced, under a pressure of about 25 atmospheres, into the bomb containing the oil, and the combustion started by means of a platinum wire heated to redness by electricity. The bomb calorimeter has recently been successfully employed by Slosson and Colburn[1] in the determination of the thermal value of petroleum. Mahler's form of bomb, which has a thin internal coating of enamel, was used.

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[1] *Census Report on Petroleum.*

PETROLEUM SPIRIT AND SHALE SPIRIT.

The rules of the New York Produce Exchange relating to United States petroleum spirit provide that—"Naphtha shall be water white, and sweet, and of gravity of from 68° to 73° B."

It is important that petroleum spirit or shale spirit intended for use in the carburetting of air or gas, should be fairly homogeneous in composition, and especially that it should not contain an undue proportion of hydrocarbons of comparatively high boiling point. It is, therefore, frequently necessary to subject samples of gasoline to the test of fractional distillation, and to determine the range of boiling points, in addition to ascertaining the density of the spirit. In taking the boiling points, the author is accustomed to employ an ordinary distillation flask, with the bulb of the thermometer a short distance above the surface of the liquid.

Fractional Distillation Test for Petroleum Spirit—Kissling's Distilling Apparatus.—The following method of fractionating petroleum spirit is adopted in the laboratory of Dr. Richard Kissling[2] :—A distilling flask (the Engler flask already described) is charged with 100 c.c. of the benzine to be tested, and connected with a Liebig's condenser 60 cm. in length, which discharges into a measuring glass graduated to ½ c.c. The flask is supported by wire gauze such as is used in the filter presses of sugar refineries. At the beginning of the operation, it is advisable to let the bent end of the adapter dip as far into the glass as possible, to minimise the evaporation of the lightest fractions. The rate of distillation recommended is 2 to 2½ c.c. per minute. At first, the temperature usually rises rapidly, then more slowly until it reaches a point where it remains practically stationary. This is the "lower boiling limit" of the benzine under examination. At every rise of 10° from this point (beginning with the first even 10°) the volume of distillate is read off. Finally, when the bottom of the flask is free from liquid, a Bunsen flame is applied, and the temperature registered is considered as the "upper limit" of boiling. For this it is not necessary to drive off the last high-boiling portions (which at most amount to 0·1 to 0·2 per cent.). To ascertain their boiling points, the thermometer must be lowered to the bottom of the neck of the flask. In the following table, Kissling gives the results of distillations thus conducted :—

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[1] *Special Bulletin of the University of Wyoming*, January, 1895.

[2] *Chemiker Zeitung*, xiv., 1890, 508.

Benzine Tested.	Guaranteed boiling limits.	Distillate (in c.c.) up to											Lower boiling limit.	Higher boiling limit.
		30 °C.	40 °C.	50 °C.	60 °C.	70 °C.	80 °C.	90 °C.	100 °C.	110 °C.	120 °C.	130 °C.		
	°C												°C.	°C.
1. Gasoline, . (Petroleum ether)	30 to 100	0	37	66	81	95	97	97·5	98	...	...	...	31	121 (98 %)
2. Light Benzine, .	60 to 100	...	...	...	0	53	89	96·5	97·5	98	98·5	...	62	123 (99 %)
3. Intermediate Benzine,	80 to 120	...	...	...	...	...	0	59	98	98·5	99	...	80	119 (99 %)
4. Heavy Benzine, .	100 to 130	...	...	...	...	...	...	...	0	57	94	99	101	138 (99½ %)

KEROSENE AND PARAFFIN OIL.

The following are the rules of the New York Produce Exchange relating to kerosene:—"Refined petroleum shall be standard white or better, with a burning test of 110° F. or upward, and of a specific gravity not below 44° B., United States Dispensatory Standard."

"The burning test of refined petroleum shall be determined by the use of the Saybolt Electric Instrument, and shall be operated in arriving at a result as follows:—In 110° and upwards, the flashing points, after the first flash (which will generally occur between 90° and 95°), shall be taken at 95°, 100°, 104°, 108°, 110°, 112°, and 115°. In 120° and upwards, after first flash, at 100°, 105°, 110°, 115°, 118°, 120°, 122°, and 125°. In 130° and upwards, every five degrees until burning point is reached."

The rules of the Petrolia (Canada) Oil Exchange provide that refined kerosene shall be of the odour "locally known as inoffensive," and shall "absolutely stand the test of oxide of lead in a strong solution of caustic soda without change of colour." The "burning percentage" in the case of "extra refined oil," "water white" in colour, and of specific gravity not exceeding 0·800, is required to be not less than 70; in the case of "No. 1 refined oil," "prime white" in colour, not less than 60; and in the case of "No. 2 refined oil," "standard white" in colour, to be not less than 55. The "burning percentage" is ascertained in the manner described on pp. 542 to 544.

The following are the recognised tests applied to Russian kerosene in the principal refineries in Baku:—1. The oil must be clear and bright, and in case it has become opalescent through contact with water, it must, when poured into an open glass, become bright at a moderate temperature (15° C.). 2. The odour must be "pure." 3. The colour should not be below 2½ (midway between "superfine white" and "prime white)." 4. The flashing point, Abel-Pensky test, must not be lower than 28° C. 5. The distillation test is made in a flask of 500 c.c. capacity, which is wrapped round six or eight times with fine wire gauze, over a naked gas or spirit flame. The distillation is conducted at such a rate that about 2 grammes is distilled per minute. As soon as the limit of the spirit is reached (150° C.) the rate of distillation is reduced so that only one-half of a gramme comes over per minute, and the temperature is then gradually increased so that 2 grammes per minute is distilled. The charge placed in the flask is 250 grammes. All products distilling below 150° C. should be considered spirit; from 150° to 270°, normal kerosene (some adopt 275° or 280° as the limit); and above 270°, heavy oils. A good kerosene may contain, according to the season of the year, from 9 to 14 per cent. of spirit, of specific gravity about 0·771 to 0·774 at 17½° C.; from 67 to 88 per cent. of normal kerosene, of specific gravity about 0·824 to 0·827; and from 9 to 13 per cent. of heavy oils, of specific gravity about 0·863 to 0·865. 6. Ash test: 1,000 grammes is distilled down in a retort (wrapped round with wire gauze) to about 40 grammes. The remainder is then boiled down in a platinum capsule, and the residue strongly heated until all the carbon is burnt. There should not be more than 10 milligrammes of ash. 7. Soda test, for "soaps." 500 c.c. of the oil is heated in a flask with 10 c.c. of caustic soda solution (1·014 specific gravity) to 70° C., the two liquids thoroughly shaken together for three minutes, allowed to stand for some time, and the oil decanted off. The soda solution is filtered, and distinctly acidulated with hydrochloric acid. The solution thus obtained should be only slightly opalescent, so that through a column half an inch in length, the finest writing can be distinctly read. The following is a scale adopted in some cases:—No. 0, quite bright; No. 1, slightly opalescent; No. 2, opalescent, so that fine hand-writing can be read; No. 3, opalescent, so that only large characters are readable; No. 4, opalescent, so that large characters are only visible; No. 5, milky. Further information relative to this test will be found in the latter part of this section. 8. Photometric test. 375 grammes of the oil is burnt, during nine hours, in a Kumberg lamp with a ten-line flat burner. The illuminating power is taken at the expiration of the first quarter of an hour (when it is usually from 10 to 11 candles), and again as soon as 80 millimetres in depth of the oil in the lamp reservoir has been burnt. Good oil should not lose more than 20 per cent. of its illuminating power, the diminution with the best oil being from 3 to 9 per cent. 9. The oil should be absolutely neutral. The test should be made with a pale but very sensitive solution of litmus in 60 per cent. spirit. 200 c.c. of the oil should be shaken with 10 c.c. of the litmus solution. 10. Sulphuric acid test (usually omitted). 4 c.c. of the oil is shaken for two minutes thoroughly with 2 c.c. of sulphuric acid of 1·835 specific gravity. The kerosene should not turn red-brown.

The Distillation Test for Burning Oil.—Dr. Engler[1] strongly recommends fractional distillation as a test for burning oil, in conjunction with the determination of the flashing point and viscosity, it being important, in his opinion, to know not only the proportion boiling between 150° and 300° C. (or other maximum limit fixed with due regard to the character of the oil), but in addition, the amounts of the intermediate fractions, as also affecting the burning quality of an oil. The precise manner in which Engler applies the test has already been described in connection with the examination of crude petroleum. With reference to the 150° to 300° limits, Beilstein[1] considers that a good oil should contain not more than 5 per cent. of hydrocarbons having boiling points below these limits, nor more than 15 per cent. having boiling points above, but it is evident that this rule does not admit of universal application. J. Biel[2] distils 250 grammes of the sample in a 500 c.c. flask, wrapped tightly with brass gauze or glass wool to protect it from too rapid changes of temperature. The flask is fitted with a Glynsky's dephlegmator, in which a thermometer is inserted so that the bulb is on a level with the exit tube. At first a small flame is applied to drive off the lighter products, and this gentle heat is maintained as long as any notable quantity (more than 10 drops per minute) distils at 150° C. The flame is then enlarged, and a product obtained distilling between 150° and 270°, this being the "normal" kerosene. In this manner, the following results were obtained with typical samples of Russian kerosene and solar oil or pyronaphtha:—

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[1] Post's *Chemisch-technische Analyse*, 2nd ed., i., 276-278.

	Kerosene.			Pyronaphtha.	
	A.	B.	C.	D.	E.
Specific gravity, . .	0·820	0·820	0·835	0·857	0·867
Flashing point, . .	52·5° C.	35·0° C.	44·5° C.	75·0° C.	94·0° C.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Below 150° C., . . .	0·8	10·0	6·0	0·0	0·0
150° to 270° C., . .	92·0	76·5	63·5	44·5	30·5
Residue, ...	7·2	13·5	30·5	55·5	69·5

Working with a glass retort, with the bulb of the thermometer immersed in the oil, Biel obtained the following results:—

	American.		Russian.	
	No. 1.	No. 2.	No. 1.	No. 2.
Specific gravity, . . .	0·795	0·783	0·803	0·822
Flashing point, . . .	26° C.	48° C.	26° C.	30° C.
	Per cent.	Per cent.	Per cent.	Per cent.
Below 150° C., . . .	14·4	2·2	33·5	12·8
150° to 270° C., . . .	45·9	87·8	66·5	78·3
Residue, ...	39·7	10·0	...	8·4

The following results were obtained by the author in the fractional distillation of typical samples of American and Russian kerosene. A measured quantity was distilled, and the density of each fraction of 10 per cent. by volume was determined:—

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[1] *Zeitschrift f. Anal. Chemie*, xxii., 313.

[2] *Dingler's polytech. Journ.*, cclii., 119.

Number of Fractions.	American. Sp. gr, 0·803.	Russian. Sp. gr. 0·822.
1	0·748	0·783
2	0·759	0·796
3	0·778	0·803
4	0·792	0·814
5	0·802	0·827
6	0·812	0·831
7	0·822	0·837
8	0·831	0·838
9	0·838	0·846
Residue	0·849	0·864

Dr. Thörner[1] employs a distillation flask made of copper. The flask is about 200 c.c. capacity, has a neck 12 cm. long and 1·8 cm. wide, and an exit tube, serving as a condenser, 45 cm. long and 0·7 cm. wide. This tube is bent downwards at the end, and introduced into the measuring cylinder, which holds 100 c.c. up to two-thirds of its height, and is divided into 0·5 c.c. The cylinder is placed in a cooling vessel. The flask is charged with 100 c.c. of the oil, and the distillation occupies from 25 to 30 minutes. The bulb of the thermometer is apparently placed half way between the exit tube and the bottom of the neck of the flask.

Burning Quality Test.—Although the distillation test affords an indication of the value of an oil for illuminating purposes, more practical results are obtained by burning the oil in lamps under conditions as close as possible to those existing in ordinary use.

In most of the United States refineries, the oil is tested by burning it in lamps of ordinary construction, and noting the diminution in the size of the flame after a certain time. The results thus obtained depend upon many variable conditions, and attempts have been made to eliminate some of the sources of variation.

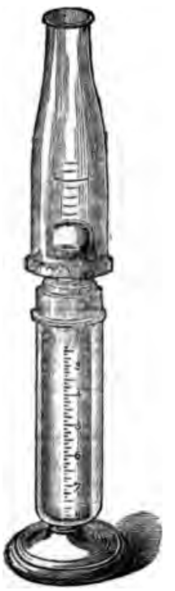

Fig. 195.

Saybolt's Apparatus.—The Saybolt testing lamp (Fig. 195) consists of a tall graduated glass vessel with a burner which gives a flame of considerable height in comparison with its width. The chimney is also graduated so that the height of the flame may be measured. A carefully selected wick is used, and the lamp is burned with the reservoir in a vessel of water at 60° F. The depression of the oil level and the diminution in the height of the flame at the expiration of a given time are noted, and the "burning quality" of the oil is judged therefrom.

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[1] *Chem. Zeit.*, x., 528-530, 553-554, 573-574, 582-583, 601-603; *Journ. Soc. Chem. Ind.*, v. (1886), 371.

Canadian Method.—In Canada, the "burning percentage" is determined by the use of a lamp thus described: "The bowl of the lamp is cylindrical; 4 inches in diameter and 2¾ inches deep, with a neck placed thereon of such a height that the top of the wick tube is 3 inches above the bowl. A sun hinge burner is used, taking a wick $\frac{7}{8}$ inch wide and $\frac{1}{8}$ inch thick, and a chimney about 8 inches long." The test is conducted as follows:—"The lamp bowl is filled with the oil and weighed, then lighted and turned up full flame, just below the smoking point, and burned without interference till 12 ounces of the oil is consumed. The quantity consumed during the first hour and the last hour is noted." The ratio of the two quantities is the measure of the burning quality, and the percentage that the latter quantity is of the former, is the "burning percentage" referred to.

Redwood's Apparatus.—In the laboratory of the author, the wicks employed in ascertaining the burning quality of oils are examined by means of the apparatus shown in Fig. 196, and any defective portion is rejected. The test consists in arranging a given length of the wick so as to draw, by capillarity, a mineral oil of known quality from a vessel, at a fixed temperature, the value of the wick being gauged by the amount of oil drawn out in a certain time. The wick is dried immediately before use, and immersed in the oil while still warm. The oil chambers of the lamps in which the tested wicks are subsequently used, must be of uniform dimensions, and the burners must be first tested to ascertain that they give similar flames with the same oil. The wick should be very carefully trimmed, and the oil in the lamp should be kept at a constant temperature, preferably at 60° F. The wick should be raised to yield the largest flame obtainable without smoke. For registering variations in the size and shape of the flame during the test, a camera is employed by the author, by means of which the outline of the flame may be traced at intervals on thin paper, as shown in Fig. 197. No general agreement has, however, been arrived at as to the extent of diminution allowable in the flame from an oil classed as of satisfactory burning quality. The apparatus

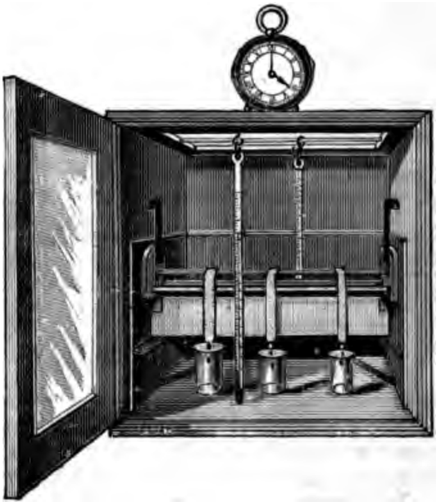

Fig. 196.

already described (Fig. 196) is also employed by the author in determining the relative capillary values of various oils.

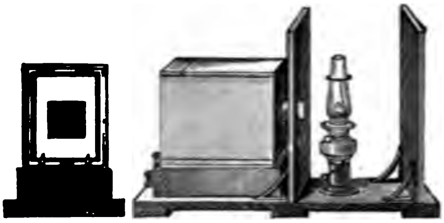

Fig. 197.

Illuminating Power.—The following table gives the results of comparative photometric tests made by the author with American kerosene and Russian kerosene (Nobel's make), in ordinary lamps with Hinks's duplex burner[1] and with two kinds of wick, one loosely woven, and the other comparatively tightly woven:—

	American kerosene.		Russian kerosene.	
	Loosely-woven wick.	Tightly-woven wick.	Loosely-woven wick.	Tightly-woven wick.
	Standard candles.	Standard candles.	Standard candles.	Standard candles.
Maximum illuminating power, . . .	25·59	24·25	22·1	19·14
Minimum illuminating power, after six hours, ...	22·24	19·16	20·5	17·4
Average illuminating power, during six hours, ...	23·96	22·14	21·2	18·04
	Per cent.	Per cent.	Per cent.	Per cent.
Diminution in illuminating power, in six hours, ...	13·0	20·9	7·2	9·0
	Grains.	Grains.	Grains.	Grains.
Oil consumed per hour, ...	1238	1213	1137	981·6
Oil consumed per candle-light per hour, .	51·6	54·7	53·6	54·4

The Russian oil did not give as much light as the American, but there was much less diminution in the illuminating power as the level of the oil in the reservoir became depressed.

In determining the illuminating power of oils, the author is accustomed to employ a Bunsen's photometer, but the sight-box should be adjustable so as to admit of the measurement of the light-giving power, not only of the rays proceeding horizontally from the lamp, but of those projected at various angles.

Determination of Colour.—For determining the *colour* of petroleum, an operation which is particularly necessary in the case of *kerosene*, it was formerly the practice to compare the sample with a standard oil placed beside it in a bottle of similar size. This method being unsatisfactory, the author adopted the plan of placing the samples in long glass cylinders held in a frame in such a manner that the images of the glass bottoms of the cylinders could be seen side by side in a mirror. This arrangement was found more satisfactory in the case of a fluorescent liquid like petroleum, than looking down on the oils while the cylinders are placed on a white surface, but, as in the previous one, the test was vitiated by the liability of the standard samples to change colour.

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[1] These tests were not made with the present form of this burner, which has a higher illuminating power for a given consumption of oil.

The adoption by the trade of precise conditions of contract, necessitated the provision of a more exact method of testing, and more than twenty years ago, the Petroleum Association decided, under the advice of the author, to employ the Wilson chromometer, in which the colour is compared with a series of glass standards.

Wilson's Chromometer.—This instrument (Fig. 198) consists of two similar tubes, 16 inches in length, closed at each end by a screw-cap carrying a stout glass disc. Light is reflected upwards through the tubes by a mirror, and is then, by two pairs of prisms, twice reflected, and thus brought into an eyepiece. One of the tubes is filled with the oil to be tested, and beneath the other, which is empty, a disc of stained glass is placed. On looking through the eyepiece, the field is seen to be divided by a sharp line formed at the juncture of the two pairs of prisms, the two halves of the field being tinted respectively with the colour of the oil and that of the standard. An accurate comparison can thus be made. The five glass standards representing the various grades of colour recognised commercially, are prepared by Mr. Robert Redwood, and are known as—

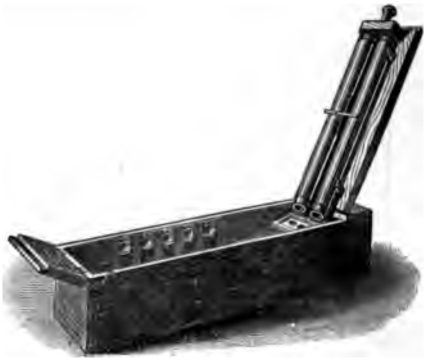

Fig. 198.

1. Water white.
2. Superfine white.
3. Prime white.
4. Standard white.
5. Good merchantable.

Although this apparatus answers well for ordinary work, it does not serve to absolutely define the shade of colour of a sample, or to indicate the extent to which it differs from the standard.

Stammer's Chromometer.—To meet this want, the Stammer chromometer was introduced, in which the length of the oil column can be varied, so that, by starting with a standard of paler tint than that of the sample, the column of oil may be shortened until the two match, and the colour of the oil may thus be found in terms of the standard. Fig. 139 shows the apparatus as made by Messrs. Schmidt & Haensch of Berlin, the parts being lettered as follows:—

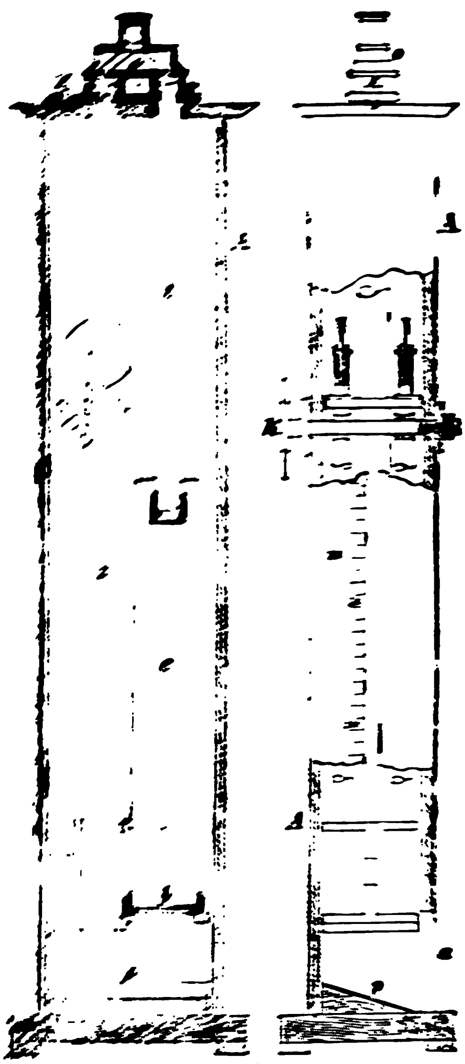

Fig. 139.

A. Case. a. Opening for passage of light to reflector. b, c. Cylinder, with glass bottom, for oil under examination. d. Hand-wheel for raising or lowering cylinder. e, f, g. Graduated scale showing length of column of oil through which light is passing. h. Optical arrangement, prisms and eye-piece. j. Reflector to project light upwards through the parallel tubes and the prisms into the eye-piece. k. Tube closed at the bottom by a glass plate. l. Coloured glass disc. m. Screw on which the optical arrangement may be turned to insert or remove the disc. n, o. Tube open at both ends.

The use of the single glass standard provided with this instrument was found by the author to be open to serious objection, as the variations in colour of different samples necessitated the shortening of the column of oil so much in certain cases that the sensitiveness of the test became greatly impaired. Several important modifications introduced by Mr. Robert Redwood have, however, overcome this defect, and by means of the improved instrument employed in the author's laboratory it is easy to accurately record the colour of any sample on a scale ranging from "water-white" (1) "to good merchantable" (5). The space between any two of the five shades is divided into ten equal parts, so that if the colour, for instance, of a sample is midway between "water-white" and "superfine white" it would be indicated by the figure 1·5.

Determination of Odour.—Some experience is required in recording the odour of kerosene, for due consideration must be given to the origin and grade of the oil under examination. The points to be noticed are whether the odour is indicative of imperfect refining, and in the case of oil in barrels, whether the glue used to coat the inner surface of the packages has become decomposed and imparted an odour to the oil. Usually the odour is reported as "good-merchantable" or "not good merchantable."

Determination of Flashing Point and Fire Test.—The temperature at which a mineral oil, on being slowly heated, begins to evolve vapour in such quantity that on the application of a flame (the "test flame") a momentary "flash," due to the ignition of the vapour, occurs, is termed the "flashing point;" and the temperature at which, on being further heated, the oil takes fire on the approach of a flame, and continues burning, is described as the "fire test" of the sample under examination. The flashing point is an arbitrary test, the results depending upon the conditions under which the test is made. Most of the instruments constructed for the purpose may be described as belonging either to the "open test" class, or to the "close test" class. In the former division, the vessel holding the sample of oil is uncovered, and in the latter, it is covered during the progress of the experiment. The temperature at which the flashing point is reached in close test instruments is usually considerably lower than that at which it is observed in open test instruments.

The testing of the flashing point or igniting point of kerosene is of the greatest importance, and forms the basis of legislation on petroleum in most civilised countries. The customary limitation of specific gravity prevents the introduction of an undue proportion of the heavier hydrocarbons, which would injuriously affect the burning quality of the oil, but affords no security against the presence of very volatile hydrocarbons, which would render the oil unsafe for use in lamps of the ordinary construction. Accordingly, in the early days of the petroleum industry in the United States, it was the practice to test kerosene by pouring it upon a warmed surface and applying a light, or by heating it in a cup placed in warmed water and bringing a burning taper near the surface, the flashing point or fire test being thus ascertained.

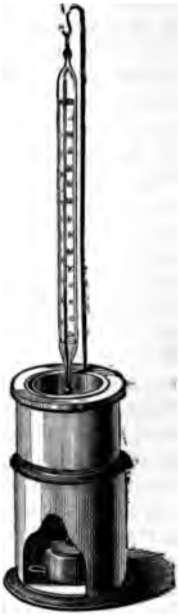

Fig. 200.

Tagliabue's Open Test Instrument.—When legal restrictions as to the inflammability of kerosene were imposed, special forms of apparatus for determining the flashing point and fire test were devised, the earliest of these being the open test instrument of Guiseppe Tagliabue of New-York. This (Fig. 200) consists of a glass cup placed in a copper water bath heated by a spirit lamp. The cup is filled with the oil to be tested, a thermometer placed in it, and heat applied, the temperatures being noted at which on passing a lighted splinter of wood over the surface of the oil, a flash occurs, and, after further heating, the oil ignites.

Early Legislation in the United Kingdom.—The Petroleum Act of July 29, 1862, states that "Petroleum, for the purposes of this Act, shall include any product thereof that gives off an inflammable vapour at less than 100° of Fahrenheit's thermometer," but as no method of testing was prescribed, the Act remained practically inoperative. On July 13, 1868, after the subject had been experimentally investigated by Sir Frederick Abel, Professor Attfield, and the late Dr. Letheby, an Act was passed which prescribed the form of apparatus and method of testing to be adopted, and defined "petroleum" for the purposes of the two Acts as including "all such rock oil, Rangoon oil, Burmah oil, any product of them, and any oil made from petroleum, coal, schist, shale, peat, or other bituminous substance, and any product of them, as gives off an inflammable vapour at a temperature of less than 100° of Fahrenheit's thermometer." It was at first intended that the oil cup should be 3 inches in depth and 1½ inch in diameter, and that it should be about one-half filled, but these conditions were subsequently modified. The prescribed apparatus for testing consists of a slightly conical oil cup of thin sheet-iron, provided with a flat rim, and a raised edge ¼ inch high. Across the cup and fixed to or resting on the edge, is a wire, which is thus ¼ inch above the flat rim. The oil cup is supported by the rim in a tin water bath. The outer vessel having been filled with "cold or nearly cold water," as much of the oil to be tested is poured into the cup as will fill it without flowing over the flat rim, and a thermometer with a round bulb, and so graduated that every 10° F. occupies not less than ½ inch on the scale, is then suspended in the oil so that the bulb is immersed about 1½ inch beneath the surface. A screen of pasteboard or wood of specified dimensions having been placed round the apparatus, a "small" flame is applied to the bottom of the water bath, and when the temperature of the oil has reached 90° F., a "very small" flame is passed across the surface of the oil on a level with the wire, this application of the test flame being repeated for every rise of "two or three" degrees in temperature, until a "pale-blue flicker or flash" is produced. The temperature at which this occurs having been noted, the experiment is repeated with a fresh sample of the oil, withdrawing the source of heat when the temperature approaches that noted in the first experiment, and applying the test flame at every rise of two degrees. In the use of this apparatus, it was found that oils of 120° F. fire test, as determined in the United States before shipment, usually had a flashing point several degrees above the legal limit of 100° F.

Early Legislation in France.—The first directions issued in respect to the testing of petroleum in France, were contained in the decree of the 31st December, 1866. The permissible weight of 1 litre of the oil was not to exceed 800 grammes, and the burning point of the oil was not to be below 35° C. The test of inflammability was to be applied by heating the oil in a copper cup 6 to 7 centimetres in diameter by 2 to 3 centimetres in depth, in a water bath, and when a thermometer placed in the oil indicated 35° C., a lighted match was to be drawn across the surface of the oil and finally plunged into the liquid. If the match was extinguished without igniting the oil, the latter was considered to have passed the test.

Early Legislation in the United States.—Most of the earlier petroleum legislation in the United States was based on the fire test, but in several of the States, a flashing-point test was prescribed.

Squire's Open Test Apparatus.—This was designed with a view to the ready adjustment of the test flame to the required height above the surface of the oil. The oil cup was heated in a water bath as usual, but the test flame was furnished by a wick slightly protruding from a long tube extending from the side of a cylindrical reservoir charged with spirit. The reservoir was carried by an arm which swung on a vertical rod attached to a heavy base, separate from the water bath, and the height of it could be adjusted by means of a screw, so that the flame could, by swinging the lamp, be caused to pass over the oil at any desired distance from the surface.

The inventor's directions were:—For 110° oil, the cup should be filled to within one-eighth of an inch from the top, the bulb of the thermometer extended into the oil up to the first cut line, and the height of the test flame fixed at three-sixteenths of an inch above the edge of the cup, or five-sixteenths of an inch above the surface of the oil. The apparatus should stand quite level, and the test flame should be trimmed down to about the size of a dried pea. The heat of the lamp should be so regulated as to raise the temperature of the oil 5° in the first four minutes, and afterwards 10° every three minutes until 90° is reached, at which point the lamp is withdrawn for three minutes to allow the temperature to become stationary (at 96° to 98°), when the test flame is swung, beginning at 2 inches from the cup and terminating at the same distance on the other side, the movement occupying about half a second. If no flash occurs, the test flame is again swung after a lapse of ten seconds, repeating the operation every two or three degrees until the burning point is reached. The lamp should be removed before a test is made, until the temperature becomes stationary. For 120° oil, the lamp should be allowed to remain until the thermometer indicates 100°, the tests being then applied in the manner described, only at every four or five degrees.

Arnaboldi's Tester.—An open cup tester similar to that of Tagliabue, but of somewhat larger size, and provided with a mechanical arrangement for passing the test flame over the oil, was introduced by Arnaboldi.

Saybolt's Electric Tester.—In 1879, the Saybolt electric tester (Fig. 201) was adopted by the New York Produce Exchange. In this apparatus, the oil is contained in an open cup, and ignition is effected by a spark from an induction coil, passing between platinum points placed at a fixed distance above the oil. The official directions for the use of the apparatus are as follows:—

"Fill the metal bath with water, leaving room for displacement by the glass cup. Heat the water until the bath thermometer indicates 100° F., at which point remove the lamp. Fill the glass cup with oil to top line, indicated by the rim surrounding cup, which is one-eighth of an inch below top edge of the cup. See that there is no oil on the outside of the cup, nor upon the upper level edge, using paper to clean cup in preference to cotton or woollen material. See that the surface of the oil is free from air bubbles before first flash is produced. Lift the cup steadily with left hand and place in the bath. Suspend the thermometer with the bulb of same immersed just from view under the surface of oil. Adjust the flashing bar and immerse the battery zincs in fluid. Try for first flash every degree until the same is obtained. Attain flash by producing spark with one stroke of the key. The stroke on the key should be such as in telegraphy is used to produce what is called a dot, that is a short quick stroke. The first flash produced from 110° test oil is generally obtained when the temperature of the oil has arrived at 90°. The temperature of the bath at 100° (as per note above) will carry the oil to about 90°, or, in other words, to about the first flashing point, without the aid of a lamp. When the thermometer in the oil indicates 90°, introduce lamp under the bath, and do not remove until the operation is finished. The temperature of oil when placed in bath should not be lower than 55°, nor higher than 70° F. The flashing bar must be free from oil before adjusting for test. Draughts of air must be excluded from the apartment wherein tests are made. Oil of 110° and upwards shall (after first flash) be flashed at 95, 100, 104, 108, 110, 112, 115. Oil of 120° and upwards, after first flash, 100, 105, 110, 115, 118, 120, 122, 125. Oil of 130° and upwards, every 5° after first flash, until burning point."

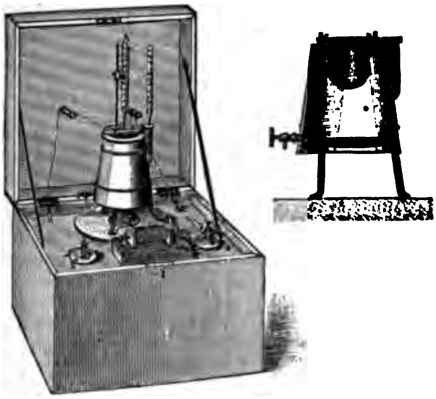

Fig. 201.

Indiana State Test.—The Indiana State Act of 1881 prescribes the method of applying the open flash test as follows:—

"The test shall be made in a test-cup of metal or glass, cylindrical in shape, two and one quarter inches in diameter and four inches deep, both measurements being made inside the cup, and this cup shall be filled to within one-quarter of an inch of the brim with the oil or other substance to be tested. The cup shall be placed in a water bath sufficiently large to leave a clear space of one inch under the cup, and three-eighths of an inch around it, and in such manner as to project about one-quarter of an inch above the water bath. The space between the cup and the water bath shall be nearly filled with cold water, taken at the ordinary temperature, and the cup being placed in the water bath, the latter shall be heated by an alcohol lamp, with its flame so graduated that the rise in temperature, from 60° F. to the highest test temperature, shall not be less than 2° per minute, and shall be as near 2° per minute as is practicable, and shall in no case exceed 4° per minute. A Fahrenheit thermometer shall be suspended in such manner that the upper surface of its bulb shall be, as near as practicable, one-quarter of an inch below the surface of the oil undergoing the test; as soon as the temperature reaches the point of 98° F., the lamp shall be removed from under the water bath, and the oil shall then be allowed to rise to the temperature of 100° F. by the residual heat of the water, and at that point the first test for flash shall be made as follows:—A taper, hereinafter described, shall be lighted, and the surface of the oil shall be touched with the flame of the taper, and it shall be lawful to apply this flame either to the centre of the oil surface or to any or all parts of it, but the taper itself shall not be plunged into the oil, and if no flash takes place at the temperature of 100° F., the lamp shall be replaced under the water bath, and the temperature raised to 103°, when the lamp shall be again withdrawn, and allowed to rise to 105° by the residual heat of the water, when the test shall be made at 105° by again applying the flame of the taper, as hereinbefore specified. If no flash occur, the test shall be repeated as often as the oil gains 5° in temperature, 3° with the lamp under the water bath, and 2° with the lamp removed. These tests shall be repeated until a flash is obtained. The Inspector shall further test the oil by applying the taper at every 2° rise, without removing the lamp or stirring; but if a flash is obtained by this means by a less rise in temperature than 5° herein required, he shall at once remove the lamp, stir the oil, and immediately apply the flame. The taper used for testing may be made of any wood giving a clear flame, and it shall be made as slender as possible, and with a tip not more than one-sixteenth of an inch in thickness. No taper or match with sulphur on it shall be used, unless the sulphur is first removed before lighting. When the taper is lighted, it shall be applied to the oil immediately—that is to say, before an ash or coal has time to form on the end of the taper beyond the flame, and, in applying the taper, the flame shall be made to touch the oil, but the taper itself shall not be brought in contact with the oil: Provided, That, if the taper is so brought in contact with the oil, but not held there longer than for the space of one second, and the oil flashes, the test shall not thereby be vitiated, but the Inspector shall immediately remove the lamp, and again test the oil by the flame, without allowing the body of the taper to touch the oil."

The **Minnesota State** testing instrument also belongs to the open test class.

Danish Tester.—An instrument similar to that of Tagliabue, but with an oil cup made of copper, is described[1] as the *Danish Tester*, and is said to be the instrument at one time officially used in Denmark. In carrying out the test, the water bath is filled with water to a mark, the oil cup is inserted and filled with oil up to a mark, and the thermometer is placed in such a position that its bulb is just covered by the oil. The temperature is gradually raised, and from time to time, a small flame—that of a wooden match, for example—is brought within a short distance of the surface of the oil (care being taken not to touch either the oil or the walls of the cup), until a flash is observed. In repeating the test, the oil cup must be cooled before being filled with a fresh portion of the oil, and the water bath re-charged with cold water.

Defects in the English Legal Test of 1868.—It was soon found that the directions for testing given in the English Petroleum Act of 1868 were not sufficiently precise, and that the words "small flame" and "very small flame" were differently interpreted by various operators. As the result, dealers were frequently proceeded against, and sometimes convicted, for selling kerosene flashing below the legal limit, although the oil had been passed by independent experts. Moreover, it was found that the open cup tests were very unreliable, especially when made by comparatively unskilled and inexperienced persons.

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[1] *Zeits. f. anal. Chemie* for 1881, xx., 11.

Keates's Close Test Instrument.—The substitution of a closed or covered oil cup (Fig. 202) for the open cup was accordingly proposed by Mr. Keates, consulting chemist of the Metropolitan Board of Works. In 1871, a bill to legalise this change and to otherwise amend the existing law was introduced, but it was opposed by the petroleum trade on the ground that the flashing point of 85° F. advocated by Mr. Keates was much higher than the equivalent of the standard of 100° F. in use with the open cup.

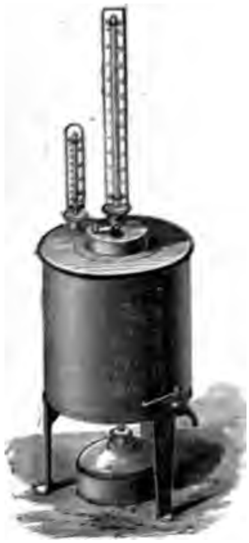

Fig. 202.

The Act of 1871.—The Act passed on August 11, 1871, although repealing the two last Acts (see the section on Legislation), did not, therefore, effect any alteration in the mode of testing, but prescribed the use of the open cup as specified in the Act of 1868.

The Select Committee of 1872.—In the following year, a Select Committee of the House of Lords enquired into the subject of petroleum testing, but arrived at no definite conclusions.

Reference to Sir Frederick Abel.—In 1875, the Government, with the concurrence of the Metropolitan Board of Works and of the Petroleum Association, requested Sir Frederick Abel to experimentally investigate the matter, with a view to placing it on a satisfactory basis. The questions referred were as follows:—

"1. Whether the method of testing petroleum as prescribed in schedule 1 of the Petroleum Act, 1871 (34 and 35 Vict., c. 105), is such as uniformly to ensure reliable and satisfactory results.

"2. If not, what alterations in the method of testing petroleum should be adopted to secure such results, due regard being had to the fact that the testing must, in many instances, be carried out by persons who have had comparatively little experience in conducting delicate experiments.

"3. Assuming it to be, in your opinion, desirable to obtain a 'flashing test' for petroleum, whether the present 'flashing point' of 100° F. (or its equivalent under any modified method of testing which you may propose) is, in your judgment, calculated to afford adequate protection to the public, without unduly interfering with or restricting the trade; if not, what alteration in this respect should be made."

After a prolonged and exhaustive experimental inquiry, in which Dr. Kellner rendered valuable assistance, Sir Frederick Abel presented to the Secretary of State an elaborate report, dated August 12, 1876, wherein the questions enumerated were thus answered:—

(1) The method of testing petroleum as prescribed in schedule 1 of the Petroleum Act, 1871 (34 and 35 Vict., c. 105), is not of a nature "uniformly to ensure reliable and satisfactory results."

(2) A method of testing petroleum has been elaborated for adoption in place of that prescribed by the Petroleum Act, 1871, due regard having been had to the

fact "that the testing must, in many instances, be carried out by persons who have had comparatively little experience in conducting delicate experiments." This method, while resembling in its general nature the one hitherto used, is free from the defects inherent in the latter, and is so arranged that it can be carried out, with the certainty of furnishing uniform and precise results, by persons possessing no special knowledge or skill in manipulation. With ordinary attention in the first instance to simple instructions, different operators cannot fail to obtain concordant results with it, and it is so nearly automatic in its nature that it is not, like the present method of testing, susceptible of manipulation so as to furnish different results at the will of the operator.

(3) There are not, in my judgment, any well-established grounds for considering that the present flashing point of 100° F. is not "calculated to afford adequate protection to the public."

(4) With the employment of the new test, a minimum flashing point should therefore be adopted, which is equivalent, or as nearly as possible so, to the flashing point of 100° F., as furnished by the present test.

In the determination of the equivalent flashing point, it was obviously necessary to deal with the conflicting views already referred to, as to the proper mode of conducting the test with the open-cup instrument. The author was enabled to assist Sir Frederick Abel in the conduct of this portion of the enquiry, but before the test standard was even provisionally fixed, Mr. T. W. Keates, as representing the Metropolitan Board of Works, and Mr. John Calderwood, on behalf of the Scottish Mineral Oil Association, were also consulted. Eventually, as the result of the joint experiments, it was ascertained that the difference between the flashing points obtained with the open-cup instrument and those furnished by the Abel apparatus, usually ranged from 25° to 29° F. Adopting the mean difference of 27°. the new standard was accordingly fixed at 73° F. The author then applied the two tests to 1,000 samples of American kerosene, the first 968 samples consisting of the ordinary oil of commerce, and the remaining 32 of "water-white" oil. The following were the results obtained:—

92 samples showed a difference between the two tests of 25°
208 ,, ,, ,, ,, ,, 26°
225 ,, ,, ,, ,, ,, 27°
281 ,, ,, ,, ,, ,, 28°
162 ,, ,, ,, ,, ,, 29°
968

On the other hand, the majority of the last 32 samples gave smaller differences, as follows:—

9 samples showed a difference between the two tests of 20°
1 sample ,, ,, ,, ,, 21°
9 samples ,, ,, ,, ,, 22°
1 sample ,, ,, ,, ,, 23°
4 samples ,, ,, ,, ,, 24°
8 ,, ,, ,, ,, ,, 25°
32

These, however, all consisted, not of ordinary petroleum oil, but of the special kind which is known in the trade under the name of "water-white" oil, and, therefore, the exceptional results afforded by them do not affect the question at issue, and are of interest only as showing that samples may be selected or specially prepared having flashing points by the two systems more closely approximating than those of the ordinary petroleum oil of commerce. This water-white oil, as is well understood, possesses the distinctive feature of low specific gravity in addition to that of high flashing point, being in fact produced at a considerably enhanced cost, by rejecting, in the process of distilling the crude oil, an unusually large proportion of the heavier as well as of the lighter hydrocarbons, and, doubtless, this accounts for the smaller difference between the two tests.

Before the new test was legalised, the author proceeded (in 1877) to New York for the purpose of submitting the instrument to the inspectors appointed by the New York Produce Exchange, and arranging for its use in testing kerosene intended for shipment to this country.

The Abel Test.—The result of Sir Frederick's investigation was the legalisation, on August 11, 1879, of the "Abel test." The instrument and its use are thus described in the Petroleum Act of that date:—

FIRST SCHEDULE.

MODE OF TESTING PETROLEUM SO AS TO ASCERTAIN THE TEMPERATURE AT WHICH IT WILL GIVE OFF INFLAMMABLE VAPOUR.

Specification of the Test Apparatus (Figs. 203 to 205).—The following is a description of the details of the apparatus:—

The oil cup consists of a cylindrical vessel 2 inches diameter, $2\frac{2}{10}$ inches in height (internal), with outward projecting rim $\frac{5}{10}$ inch wide, ⅜ inch from the top, and 1⅞ inch from the bottom of the cup. It is made of gun-metal or brass (17 B.W.G.) tinned inside. A bracket, consisting of a short stout piece of wire bent upwards and terminating in a point, is fixed to the inside of the cup to serve as a gauge. The distance of the point from the bottom of the cup is 1½ inch. The cup is provided with a close-fitting overlapping cover made of brass (22 B.W.G.), which carries the thermometer and test lamp. The latter is suspended from two supports from the side by means of trunnions, upon which it may be made to oscillate; it is provided with a spout, the mouth of which is $\frac{1}{16}$ inch diameter. The socket which is to hold the thermometer, is fixed at such an angle and its length is so adjusted, that the bulb of the thermometer, when inserted to its full depth, shall be 1½ inch below the centre of the lid.

The cover is provided with three square holes—one in the centre, $\frac{5}{10}$ inch by $\frac{4}{10}$ inch, and two smaller ones, $\frac{3}{10}$ inch by $\frac{2}{10}$ inch, close to the sides and opposite each other. These three holes may be closed and uncovered by means of a slide moving in grooves, and having perforations corresponding to those on the lid.

In moving the slide so as to uncover the holes, the oscillating lamp is caught by a pin fixed in the slide, and tilted in such a way as to bring the end of the spout just below the surface of the lid. Upon the slide being pushed back so as to cover the holes, the lamp returns to its original position.

Upon the cover, in front of and in line with the mouth of the lamp, is fixed a white bead, the dimensions of which represent the size of the test flame to be used.

The bath or heating vessel consists of two flat-bottomed copper cylinders (24 B.W.G.)—an inner one of 3 inches diameter and 2½ inches in height, and an outer one of 5¼ inches diameter and 5¾ inches in height; they are soldered to a circular copper plate (20 B.W.G.) perforated in the centre, which forms the top of the bath, in such a manner as to enclose the space between the two cylinders, but leaving access to the inner cylinder. The top of the bath projects both outwards and inwards about ⅜ inch; that is, its diameter is about ¾ inch greater than the body of the bath, while the diameter of the circular opening in the centre is about the same amount less than that of the inner copper cylinder. To the inner projection of the top is fastened, by six small screws, a flat ring of ebonite, the screws being sunk below the surface of the ebonite to avoid metallic contact between the bath and the oil cup. The exact distance between the sides and bottom of the bath and of the oil cup is ½ inch. A split socket similar to that on the cover of the oil cup, but set at a right angle, allows a thermometer to be inserted into the space between the two cylinders. The bath is further provided with a funnel, an overflow pipe, and two loop handles.

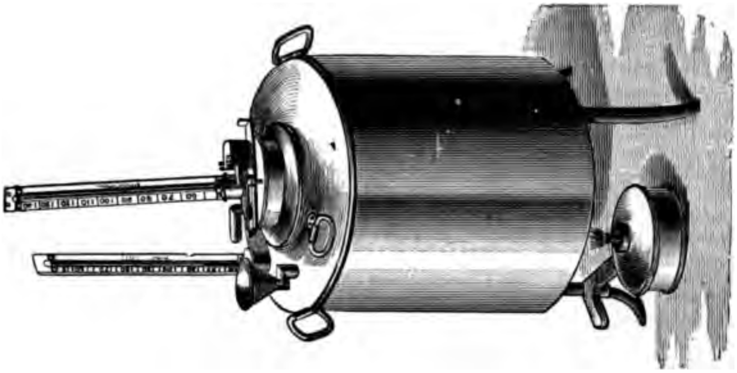

Fig. 205.

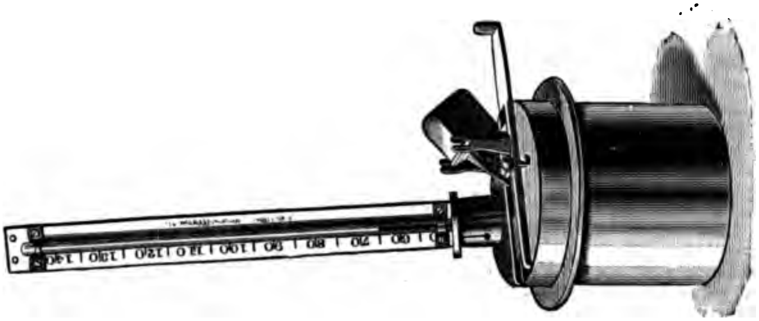

Fig. 204.

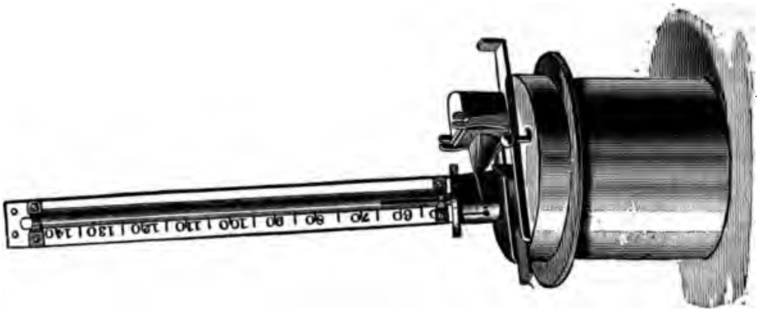

Fig. 203.

The bath rests upon a cast-iron tripod stand, to the ring of which is attached a copper cylinder or jacket (24 B.W.G.) flanged at the top, and of such dimensions that the bath, while firmly resting on the iron ring, just touches with its projecting top, the inward-turned flange. The diameter of this outer jacket is 6½ inches. One of the three legs of the stand serves as a support for the spirit lamp attached to it by means of a small swing bracket. The distance of the wick-holder from the bottom of the bath is 1 inch.

Two thermometers are provided with the apparatus—the one for ascertaining the temperature of the bath, the other for determining the flashing point. The thermometer for ascertaining the temperature of the water, has a long bulb and a space at the top. Its range is from about 90° to 190° F. The scale (in degrees of Fahrenheit) is marked on an ivory back fastened to the tube in the usual way. It is fitted with a metal collar, fitting the socket, and the part of the tube below the scale should have a length of about 3½ inches, measured from the lower end of the scale to the end of the bulb. The thermometer for ascertaining the temperature of the oil, is fitted with collar and ivory scale in a similar manner to the one described. It has a round bulb, a space at the top, and ranges from about 55° F. to 150° F.; it measures, from end of ivory back to bulb, 2¼ inches.

NOTE.—A model apparatus is deposited at the Weights and Measures Department of the Board of Trade.

DIRECTIONS FOR APPLYING THE FLASHING TEST.

1. The test apparatus is to be placed for use in a position where it is not exposed to currents of air or draughts.

2. The heating vessel or water bath is filled by pouring water into the funnel until it begins to flow out at the spout of the vessel. The temperature of the water at the commencement of the test is to be 130° F., and this is attained in the first instance either by mixing hot and cold water in the bath, or in a vessel from which the bath is filled, until the thermometer which is provided for testing the temperature of the water gives the proper indication; or by heating the water with the spirit lamp (which is attached to the stand of the apparatus) until the required temperature is indicated.

If the water has been heated too highly, it is easily reduced to 130° by pouring in cold water little by little (to replace a portion of the warm water) until the thermometer gives the proper reading.

When a test has been completed, this water bath is again raised to 130° by placing the lamp underneath, and the result is readily obtained while the petroleum cup is being emptied, cooled, and refilled with a fresh sample to be tested. The lamp is then turned on its swivel from under the apparatus, and the next test is proceeded with.

3. The test lamp is prepared for use by fitting it with a piece of flat plaited candle-wick, and filling it with colza or rape oil up to the lower edge of the opening of the spout or wick tube. The lamp is trimmed so that when lighted, it gives a flame of about 0·15 of an inch diameter,[1] and this size of flame, which is represented by the projecting white bead on the cover of the oil cup, is readily maintained by simple manipulation from time to time with a small wire trimmer.

When gas is available it may be conveniently used in place of the little oil lamp, and for this purpose a test-flame arrangement for use with gas may be substituted for the lamp.

4. The bath having been raised to the proper temperature, the oil to be tested is introduced into the petroleum cup, being poured in slowly until the level of the liquid just reaches the point of the gauge which is fixed in the cup. In warm weather the temperature of the room in which the samples to be tested have been kept should be observed in the first instance, and if it exceeds 65°, the samples to be tested should be cooled down (to about 60°) by immersing the bottles containing

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[1] It was at first intended merely to specify the size of the flame, but as it was found difficult to judge of the diameter, the bead was added at the suggestion of the author.

them in cold water, or by any other convenient method. The lid of the cup, with the slide closed, is then put on, and the cup is placed into the bath or heating vessel. The thermometer in the lid of the cup has been adjusted so as to have its bulb just immersed in the liquid, and its position is not under any circumstances to be altered. When the cup has been placed in the proper position, the scale of the thermometer faces the operator.

5. The test lamp is then placed in position upon the lid of the cup, the lead line or pendulum, which has been fixed in a convenient position in front of the operator, is set in motion, and the rise of the thermometer in the petroleum cup is watched. When the temperature has reached about 66°, the operation of testing is to be commenced, the test-flame being applied once for every rise of one degree in the following manner:—

The slide is slowly drawn open while the pendulum performs three oscillations, and is closed during the fourth oscillation.

NOTE.—If it is desired to employ the test apparatus to determine the flashing point of oils of very low volatility, the mode of proceeding is to be modified as follows:—

The air chamber which surrounds the cup is filled with cold water to a depth of 1½ inch, and the heating vessel or water bath is filled as usual, but also with cold water. The lamp is then placed under the apparatus, and kept there during the entire operation. If a very heavy oil is being dealt with, the operation may be commenced with water previously heated to 120°, instead of with cold water.

The pendulum described in (5) measures 24 inches from the point of suspension to the centre of gravity of the weight. The author has found it convenient to employ a synchronised pendulum clock, or a metronome, when making a large number of tests.

The Abel instruments employed in the United Kingdom by the inspectors appointed in accordance with the provisions of the Petroleum Acts, are standardised by the Weights and Measures Department of the Board of Trade.

Effect of Variations in Barometric Pressure.—It was soon found that the results obtained with the Abel instrument differed materially according to the barometric pressure at the time of testing. This source of variation appears to have been first observed accidentally in Germany, and as the result of a series of experiments made in an air-tight chamber in the Jewish Hospital in Berlin, it was ascertained that the difference in the flashing point amounted to about 0·30° C. for each 10 millimetres difference in the barometric column. A table of corrections was accordingly prepared in Germany for use with the Abel-Pensky tester, as described on pp. 568 and 570.

Experiments at different Altitudes in Switzerland.—To obtain further evidence as to the effect of alteration in barometric pressure on the flashing point, a series of experiments was conducted by the author in association with Sir Frederick Abel at different altitudes in Switzerland, and results exhibiting a difference of about 2° F. in the flashing point for 1 inch difference in barometric pressure, were obtained.

The experiments were, however, not carried out with a view of determining the exact extent of variation, the number of tests made being insufficient to form the basis of a table of corrections. The results actually obtained are given in the following table:—

No. of Sample.	London. Bar. at 30″	Paris. 30·15″.	Bouveret. 28·75″.	Visp. 27·5″.	Chamounix. 26·425″.	Zermatt. 24·3″.	Riffel. 21·5″.
1	71° F.	71° F.	68° F.	66° F.	63° F.	60° F.	55° F.
2	73	73	70	68	64	62	56
3	76	76	73	71	68	65	63
4	78	78	75	73	70	67	64
5	85	85	83	80	78	75	70
Difference in barometer from London observation, ...			1·25″	2·5″	3·575″	5·7″	8·5″
Mean difference in flashing point per inch of mercurial column, .			2·05°	2°	2·238°	1·93°	1·76°

Effect of a Tropical Climate.—It was also found that the effect of a tropical climate upon the liberation of vapour from the oil resulted in the flashing point being considerably lowered, and as the Indian Government, in adopting the Abel test, had copied the directions verbatim from the English Act, the result was that several cargoes of oil, which were certified as of proper flashing point at the time of shipment, were refused admittance at the port of Calcutta.

Experimental Investigations in India and in London.—In order to investigate the matter, the author proceeded to India, and from a series of experiments made there and afterwards in England in conjunction with Sir Frederick Abel and with the assistance of Dr. Kellner, it was demonstrated that a much lower flashing point than that furnished in a temperate climate was liable to be obtained when the Abel test was employed in a tropical climate in the manner prescribed in the English Act. Further experiments made by Dr. Warden, analyst to the Government of Bengal, Professor Pedler of Calcutta, Dr. Lyon, Sir Frederick Abel, Dr. Kellner, and the author showed that the depression in the flashing point was largely due to disengagement of vapour in the act of filling the oil cup. Although prolonged cooling of the oil minimised the liability to such disengagement of vapour, it was found that the only practical means of eliminating this source of error, was to get rid of the vapour before commencing the test or before the flashing point was reached.

Modification Proposed.—The vapour was readily removed by gently blowing over the surface of the oil before placing the cover on the cup, or by the use of an aspirator attached to the cover, or by leaving the test slide withdrawn for some time; but the method finally adopted consisted in commencing the test many degrees below the flashing point, so that the vapour is withdrawn by the current of air created by the test flame, in successive quantities too small to cause a flash before volatilisation of the oil begins. Thus modified, the test gives results at a tropical temperature which agree very closely with those which it furnishes in a temperate climate. The slight loss of volatile constituents which occurs when the test is so performed is of no practical importance since such loss takes place even by exposure to the air in hot climates (see a joint communication from Sir F. Abel and the author in the *Chemical News*, May 2, 1884).

Directions for conducting the Test in Temperate and Tropical Climates.—In October, 1887, Sir Frederick Abel drew up the following directions for the use of the Abel instrument in both *temperate* and *tropical* climates:—

DIRECTIONS FOR PREPARING AND USING APPARATUS FOR TESTING PETROLEUM OIL.

(*These Directions apply to the use of the Abel tester in temperate climates.*)

1. **Preparing the Water Bath.**—The water bath is filled by pouring water into the funnel until it begins to flow out at the overflow pipe. The temperature of the water at the commencement of each test, as indicated by the long-bulb thermometer, is to be 130° F., and this is attained in the first instance by mixing hot and cold water, either in the bath or in the vessel from which the bath is filled, until the thermometer which is provided for testing the temperature of the water gives the proper indication; or the water is heated by a spirit lamp (which is attached to the stand of the apparatus) until the required temperature is reached.

2. **Preparing the Test Lamp.**—The test lamp is fitted with a piece of cylindrical wick of such thickness that it fills the wick-holder, but may readily be moved to and fro for the purpose of adjusting the size of the flame. In the body of the lamp, upon the wick, which is coiled within it, is placed a small tuft of cotton-wool moistened with petroleum, any oil not absorbed by the wool being removed. When the lamp has been lighted the flame is adjusted until it is the size of the bead fixed on the cover of the oil cup.

3. **Filling the Oil Cup.**—The oil cup is placed on a level surface in a good light, and the oil to be tested is poured in without splashing, until its surface is level with the point of the gauge which is fixed in the cup. The oil should be poured from a suitable small vessel, never direct from a large can. The round-bulb thermometer is inserted into the lid of the cup, care being taken that the projecting rim of the collar touches the edge of the socket; the test lamp, prepared as already described, is placed in position, and the cover put on to the cup and pressed down so that its edge rests on the rim of the cup.

4. **The Application of the Test.**—The water bath, with its thermometer in position, is placed in some locality where it is not exposed to currents of air, and where the light is sufficiently subdued to admit of the size of the test-flame being compared with that of the bead on the cover. The cup is carefully lifted without being shaken, placed in the bath, and the test lamp lighted. The thermometer in the oil cup is now watched, and when the temperature has reached 66° F. (the sample, if necessary, having previously been cooled to below that temperature by immersing the vessel containing it, in cold water), the operation of testing is to be commenced, the test flame being applied for every rise of one degree.

If the oil cup is provided with the automatic (Pensky's) arrangement for opening and shutting the slide, the clockwork is wound up by turning the knob from left to right, and set in motion by pressing the trigger.

If the slide is intended to be moved by hand, it should be drawn open slowly and shut quickly. The exact time to be observed in this operation is regulated by the swing of the pendulum supplied with this form of instrument. The opening of the slide should take the time of three oscillations, the shutting of the slide the time of the fourth oscillation of the pendulum. (By one oscillation is meant the passage of the ball of the pendulum from the greatest distance from the vertical on the one side, to the greatest distance on the other.)

If a flash occurs at the first application of the test-flame (at 66° F.), or at any point below 73° F., the operation is to be repeated with a fresh portion of the oil, which is cooled down to 55° F. before being placed in the cup. The first application of the test-flame is made when the temperature of the oil has reached 60° F.

In repeating a test, a fresh sample of oil must always be used, the tested sample being thrown away.

5. **Correction for Atmospheric Pressure.**—As the flashing point of an oil is influenced by changes in atmospheric pressure to an average extent of 1·6° F. for every inch of the barometer, a correction of the observed flashing point may become necessary. The height of the barometer must, therefore, be determined at the time of making the test for the flashing point. An aneroid barometer is supplied for this purpose. To facilitate the correction of a flashing point for pressure a table is appended (see table following the directions for applying the test in hot climates), giving the flashing points of oils ranging from 65° to 80° F., under pressures ranging from 27 to 31 inches of mercury.

The table is used in the following manner:—

Example.—An oil has given a flashing point of 71°, the barometer being 28·6; take the nearest number to 71° in the vertical column headed 28·6. This number is 70·8. Substitute for this the number in the same horizontal line in the column headed 30 (the normal height of barometer). The substituted number—*i.e.*, the true flashing point of the oil—is 73°.

The following directions apply to the use of the Abel petroleum tester in hot climates:—

DIRECTIONS FOR DRAWING THE SAMPLE AND PREPARING IT FOR TESTING.

1. **Drawing the Sample.**—In all cases the testing officer, or some person duly authorised by him, shall personally superintend the drawing of the sample from an original unopened tin or other vessel.

An opening sufficiently large to admit of the oil being rapidly poured or siphoned from the tin or other vessel shall be made.

Two bottles, each of the capacity of about 40 fluid ounces, are to be filled with the oil. One of these, the contents of which are intended to be preserved for reference in case of need, is to be carefully corked, the cork being well driven home, cut off level with the neck, and melted sealing-wax worked into it. The other bottle may be either stoppered or corked.

2. **Preparing the Sample for Testing.**—About 10 fluid ounces of the oil, sufficient for three tests, are transferred from the bottle into which the sample has been drawn to a pint flask or bottle, which is to be immersed in water artificially cooled, until a thermometer, introduced into the oil, indicates a temperature not exceeding 50° F.

DIRECTIONS FOR PREPARING AND USING THE TEST APPARATUS.

3. **Preparing the Water Bath.**—The water bath is filled by pouring water into the funnel until it begins to flow out at the overflow pipe. The temperature of the water at the commencement of each test, as indicated by the long-bulb thermometer, is to be 130° F., and this is attained in the first instance by mixing hot and cold water, either in the bath or in a vessel from which the bath is filled, until the thermometer which is provided for testing the temperature of the water gives the proper indication; or the water is heated by means of a spirit lamp (which is attached to the stand of the apparatus) until the required temperature is indicated.

4. **Preparing the Test Lamp.**—The test lamp is fitted with a piece of cylindrical wick of such thickness that it fills the wick-holder, but may readily be moved to and fro for the purpose of adjusting the size of the flame. In the body of the lamp, upon the wick, which is coiled within it, is placed a small tuft of

cotton wool, moistened with petroleum, any oil not absorbed by the wool being removed. When the lamp has been lighted, the wick is adjusted by means of a pair of forceps, or a pin, until the flame is the size of the bead fixed on the cover of the oil cup; should a particular test occupy so long a time that the flame begins to get smaller, through the supply of oil in the lamp becoming exhausted, three or four drops of petroleum are allowed to fall upon the tuft of wool in the lamp from the dropping bottle or pipette provided for the purpose. This can be safely done without interrupting the test.

5. **Filling the Oil Cup.**—Before the oil cup is filled, the lid is to be made ready for being placed upon the cup—*i.e.*, the round-bulb thermometer is to be inserted into the socket (so that the projecting rim of the collar with which it is fitted touches the edge of the socket), and the test lamp is to be placed in position. The oil cup, having been previously cooled by placing it bottom downwards in water at a temperature not exceeding 50° F., is now to be rapidly wiped dry, placed on a level surface in a good light, and the oil to be tested is poured in without splashing until its surface is level with the point of the gauge which is fitted in the cup. The lid is then put on the cup at once, and pressed down so that its edge rests on the rim of the cup.

6. **Application of the Test.**—The water bath, with its thermometer in position, is placed in some locality where it is not exposed to currents of air, and where the light is sufficiently subdued to admit of the size of the entire test-flame being compared with that of the bead on the cover. The cup is carefully lifted, without shaking it, and placed in the bath, the test lamp is lighted, and the clockwork wound up by turning the key. The thermometer in the oil cup is now watched, and when the temperature has reached 56° F. the clockwork is set in motion by pressing the trigger.

If no flash takes place, the clockwork is at once re-wound, and the trigger pressed at 57° F., and so on, at every degree rise of temperature, until the flash occurs, or until a temperature of 95° F. has been reached.

If the flash takes place at any temperature below 77° F., the temperature at which it occurs is to be recorded. The fresh portions of the sample are then to be successively tested in a similar manner and the results recorded. If no greater difference than 2° F. exists between any two of the three recorded results, each result is to be corrected for atmospheric pressure, as hereafter described, and the average of the three corrected results is the flashing point of the sample. In the event of there being a greater difference than 2° F. between any two of the results, the series of tests is to be rejected, and a fresh series of three similarly obtained, and so on until a sufficiently concordant series is furnished, when the results are to be corrected and the average taken in the manner already described.

No flash which takes place within 8° of the temperature at which the testing is commenced, shall be accepted as the true flashing point of the sample tested. In the event of a flash occurring at or below 64° when the test is applied in the manner above described, the next testing shall be commenced 10° lower than the temperature at which the flash had been previously obtained—that is to say, at 54° or thereunder, and this procedure shall be continued until the results of three consecutive tests do not show a greater difference than 2°.

If a temperature of 76° F. has been reached without a flash occurring, the application of the test flame is to be continued until a temperature of 95° F. has been reached. If no flash has occurred up to this point, and if the petroleum is declared to be imported subject to the provisions of the Act,[1] the tests shall not be continued, and the testing officer shall certify that the petroleum has a flashing point of over 95° and is not dangerous. But if the petroleum is oil ordinarily used for lubricating purposes, and is declared to have its flashing point at or above 200°, or is oil to which a notification of the Governor in Executive Council exempting it from the operation of the Act will be applicable in the event of the flashing point being found to be at or above 120°, the test shall be continued as follows:—The oil cup is to be removed from the water bath, and the temperature of the water in the water bath is to be reduced to 95° F. by pouring cold water into the funnel

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[1] The Indian Petroleum Act is here referred to.

TABLE LX.—For Correction of Flashing Points indicated by the Test, for Variations in Barometric Pressure on either side of Thirty Inches.

Barometer in Inches.																				
27	27·2	27·4	27·6	27·8	28	28·2	28·4	28·6	28·8	29	29·2	29·4	29·6	29·8	30	30·2	30·4	30·6	30·8	31
Flashing Point in Degrees Fahrenheit.																				
60·2	60·5	60·8	61·2	61·5	61·8	62·1	62·4	62·8	63·1	63·4	63·7	64	64·4	64·7	65	65·3	65·6	66	66·3	66·6
61·2	61·5	61·8	62·2	62·5	62·8	63·1	63·4	63·8	64·1	64·4	64·7	65	65·4	65·7	66	66·3	66·6	67	67·3	67·6
62·2	62·5	62·8	63·2	63·5	63·8	64·1	64·4	64·8	65·1	65·4	65·7	66	66·4	66·7	67	67·3	67·6	68	68·3	68·6
63·2	63·5	63·8	64·2	64·5	64·8	65·1	65·4	65·8	66·1	66·4	66·7	67	67·4	67·7	68	68·3	68·6	69	69·3	69·6
64·2	64·5	64·8	65·2	65·5	65·8	66·1	66·4	66·8	67·1	67·4	67·7	68	68·4	68·7	69	69·3	69·6	70	70·3	70·6
65·2	65·5	65·8	66·2	66·5	66·8	67·1	67·4	67·8	68·1	68·4	68·7	69	69·4	69·7	70	70·3	70·6	71	71·3	71·6
66·2	66·5	66·8	67·2	67·5	67·8	68·1	68·4	68·8	69·1	69·4	69·7	70	70·4	70·7	71	71·3	71·6	72	72·3	72·6
67·2	67·5	67·8	68·2	68·5	68·8	69·1	69·4	69·8	70·1	70·4	70·7	71	71·4	71·7	72	72·3	72·6	73	73·3	73·6
68·2	68·5	68·8	69·2	69·5	69·8	70·1	70·4	70·8	71·1	71·4	71·7	72	72·4	72·7	73	73·3	73·6	74	74·3	74·6
69·2	69·5	69·8	70·2	70·5	70·8	71·1	71·4	71·8	72·1	72·4	72·7	73	73·4	73·7	74	74·3	74·6	75	75·3	75·6
70·2	70·5	70·8	71·2	71·5	71·8	72·1	72·4	72·8	73·1	73·4	73·7	74	74·4	74·7	75	75·3	75·6	76	76·3	76·6
71·2	71·5	71·8	72·2	72·5	72·8	73·1	73·4	73·8	74·1	74·4	74·7	75	75·4	75·7	76	76·3	76·6	77	77·3	77·6
72·2	72·5	72·8	73·2	73·5	73·8	74·1	74·4	74·8	75·1	75·4	75·7	76	76·4	76·7	77	77·3	77·6	78	78·3	78·6
73·2	73·5	73·8	74·2	74·5	74·8	75·1	75·4	75·8	76·1	76·4	76·7	77	77·4	77·7	78	78·3	78·6	79	79·3	79·6
74·2	74·5	74·8	75·2	75·5	75·8	76·1	76·4	76·8	77·1	77·4	77·7	78	78·4	78·7	79	79·3	79·6	80	80·3	80·6
75·2	75·5	75·8	76·2	76·5	76·8	77·1	77·4	77·8	78·1	78·4	78·7	79	79·4	79·7	80	80·3	80·6	81	81·3	81·6

(the hot water escaping by the overflow pipe). The air chamber is then to be filled to a depth of 1½ inch with water at a temperature of about 95° F., the oil cup is to be replaced in the water bath, and the spirit lamp, attached to the water bath, is to be lighted and placed underneath. The test-flame is then to be again applied from 96° F., at every degree rise of temperature as indicated by the thermometer in the oil cup, until a flash takes place, or until a temperature of 200° F. or 120° F., as the case may be, has been reached. If, during this operation, the test-flame appears to diminish in size, the lamp is to be replenished in the manner prescribed (at 4) without interrupting the test.

If a flash occurs at any temperature between 76° and 200° F., the temperature at which it occurs, subject to correction for atmospheric pressure, is the flashing point of the sample.

In repeating a test, a fresh sample of oil must always be used, the tested sample being thrown away, and the cup must be wiped dry from any adhering oil, and cooled, as already described, before receiving the fresh sample.

7. **Correction for Atmospheric Pressure.**—As the flashing point of an oil is influenced by changes in atmospheric pressure to an average extent of 1·6° F. for every inch of the barometer, a correction of the observed flashing point may become necessary. The height of the barometer must, therefore, be determined at the time of making the test for the flashing point. An aneroid barometer is supplied for this purpose. To facilitate the correction of a flashing point for pressure, a table is appended, giving flashing points of oils ranging from 65° to 80° F., under pressures ranging from 27 to 31 inches of mercury.

The table is used in the following manner:—

Example.—An oil has given a flashing point of 71°, the barometer being at 28·6; take the nearest number to 71° in the vertical column headed 28·6. This number is 70·8. Substitute for this the number in the same horizontal line in the column headed 30 (the normal height of the barometer). The substituted number—*i.e.*, the true flashing point of the oil—is 73°.

Legislation in India.—An amendment to the Indian Petroleum Act of 1886, made in 1890, with the object of eliminating the source of the discrepancies referred to, will be found in the section dealing with Legislation. The clockwork form of the instrument has been adopted in that country. Since the Abel test was legalised in India, it has been found necessary to determine the flashing point of Burma crude petroleum, which is solid at common temperatures. In testing this oil in the Abel instrument, evolution of vapour commences while the bulk of the oil in the cup remains solid, and the thermometer therefore does not indicate the temperature of the oil in contact with the walls of the cup from which vapour is being evolved. To meet this difficulty, the author suggested the addition of a delicate thermometer, which is fixed in the cover of the oil cup in a vertical position, so that the small cylindrical bulb is just immersed in the oil, and is distant only a tenth of an inch from the side of the cup. This modification was favourably reported upon by Sir Frederick Abel.

Use of Abel Test in other Countries.—The various countries where the Abel tester in its original and modified forms are in use, and the respective minimum flashing points prescribed, are also given under Legislation.

The Abel-Pensky Instrument.—In 1880, the subject of petroleum testing was investigated in Germany on behalf of the Government, and the Abel instrument was selected as the best, but, as exception was taken to the personal error liable to be introduced by the method of applying the test-flame, the modification devised by Pensky, of Berlin, was adopted. The improvement consists in effecting the movement of the slide and application of the test-flame by a clockwork arrangement, which ensures uniformity. A section of the instrument—which in all other respects is practically identical with the ordinary Abel apparatus—and the details of the clockwork mechanism, are shown in Figs. 206 and 207, which also give the dimensions in millimetres.

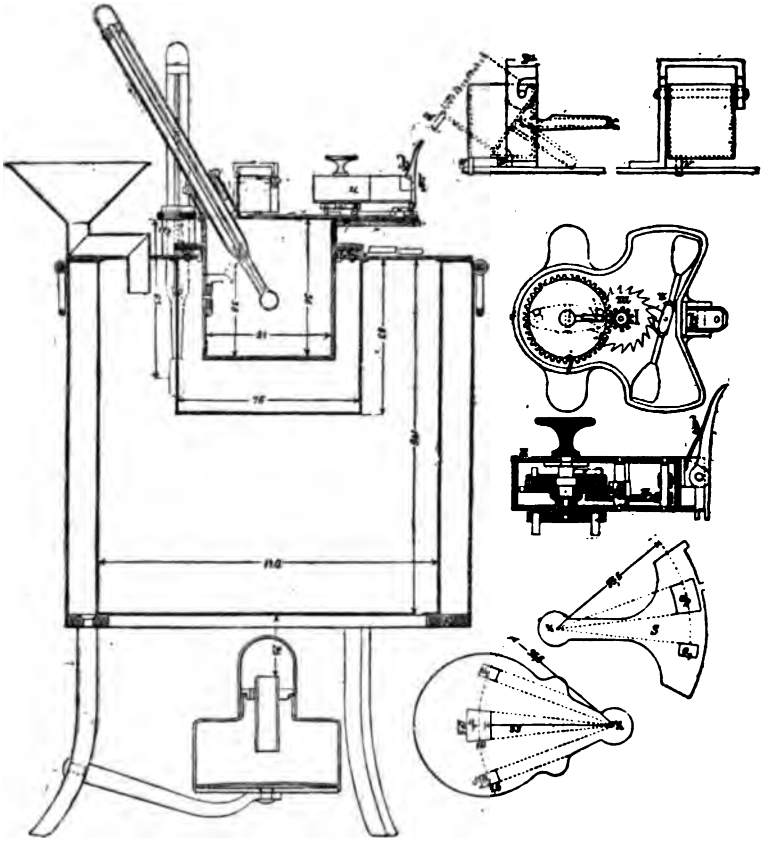

Fig. 206.

The slide, S, pivoted on the centre, *z*, is set in motion by the arm, *d*, moving on a central axis. This arm carries on its under side two pins, e_1, e_2. When the slide is in its normal position—*i.e.*, closing the openings, o_1, o_2, o_3—one of the pins, e_1, rests against the steel plate, *f*, on the right-hand side of the slide, and the other, e_2, is held by the catch *g*. On the axis of the arm *d* is fastened the spring-case *u* containing a spiral spring.

To wind up the clockwork, the knob *b* is turned half round, further winding being prevented by a stop. To move the slide, the trigger *k* is pushed towards the spring *h*, the catch *g* being thus drawn back and the pin e_2 released. The spiral spring unwinds and presses the other pin, e_1, against the slide S, moving this slide aside to the left and uncovering the apertures. As soon as the pin e_1 is carried by the revolution of the arm *d* past the steel plate *f*, the slide is forced back to its former position by the spring *r*, and the pin e_1 is stopped by the

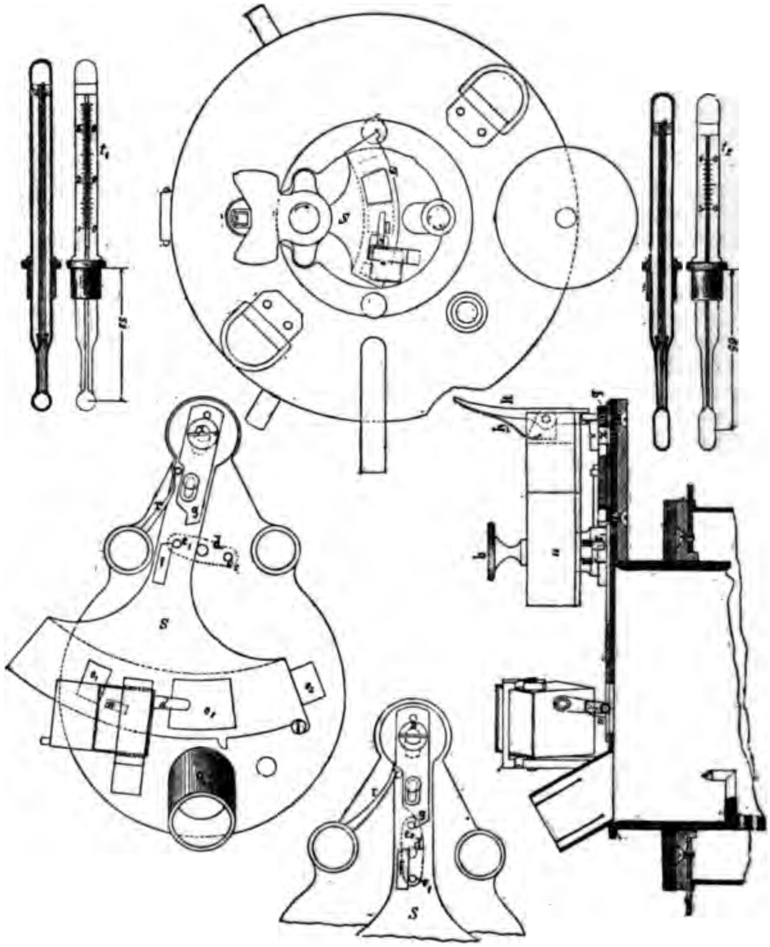

Fig. 207.

catch *g*, which returns it to its original place as the trigger *k* is released. These movements are repeated every time the test is applied. The uncoiling of the spiral spring and movement of the slide, are regulated by the escapement, *m n p*. The three holes in the lid of the oil cup, and the two holes in the slide (the lateral movement of the slide uncovering and covering the third hole in the lid) are of the same dimensions as those in the Abel instrument, but not quite the same shape, on account of the circular motion of the slide. The lamp is tipped by a nosepiece, *n*, and on its return to the perpendicular, is prevented from swinging backwards by a stop, *v*.

The Abel-Pensky apparatus, as used in Germany, furnishes results about 3° F. higher than those given by the Abel instrument, but the clockwork modification employed in India is standardised to afford flashing points corresponding with those obtained with the original Abel instrument.

Directions for the Use of the Instrument.—The following is the method of applying the Abel-Pensky test prescribed in Germany[1]:—

The testing should be carried out in an apartment of medium temperature and free from draughts. The petroleum samples should be in closed vessels and have been long enough in the room to have acquired the same temperature, otherwise the tests will not be satisfactory.

The height of the barometer must be observed before commencing operations, and the temperature at which the test is to be first applied varies with the pressure indicated, according to the following table:—

Height of Barometer.	First Test applied at
685 to 695 millimetres,	+ 14° C.
695 to 705 ,,	14°
705 to 715 ,,	14·5°
715 to 725 ,,	15°
725 to 735 ,,	15·5°
735 to 745 ,,	16°
745 to 755 ,,	16·5°
755 to 765 ,,	17°
765 to 775 ,,	17°
775 to 785 ,,	17·5°

If the barometer varies from the normal pressure of 760 mm. by more than 2½ mm. either way, the actual flashing point observed is corrected in accordance with Table LXI. The table being arranged for intervals of 5 mm., intermediate pressures are counted as 0 or 5, according to the figure which they most nearly approach—viz., 742 counts as 740, 743 as 745, and so on. The instrument must be set level on the testing table, with the aid of a spirit-level or plumb-line, before it is filled, and it should be at such a height that the red mark on the water bath thermometer is on a level with the eye of the operator. The bath is next filled with water at +50° to 52° C. until a portion runs out through the overflow pipe, to which an indiarubber tube should be attached to convey the surplus water away without splashing the apparatus or table. If cold water is used for filling the bath, it must be warmed by the heating lamp before putting in the oil cup, care being taken that the base ring does not get overheated. The test lamp is prepared for use by being packed with loose cotton wool, which is then saturated with petroleum, any surplus being poured out. If this is not attended to, the tipping of the lamp at the moment of applying the test might cause drops of oil to fall on to the lid of the tester and vitiate the results. The wick must also be cleansed from any adherent incrustation or char. The oil cup, with its cover and thermometer, are to be thoroughly clean and dry, and all traces of oil from preceding tests are to be removed by drying and absorption. Finally, the petroleum to be tested, if not at least 2° cooler than the lowest of the temperatures recorded in the foregoing table, must be cooled down to that point, together with the oil cup, the latter being dipped into cold water. To obtain very exact results, it is advisable to use water cooled to + 11° C. for this purpose, and to keep the oil cup in it long enough for proper cooling. Before inserting the oil cup, the water bath is heated up to 54° to 55° C., the temperature indicated by the red mark on the thermometer scale. Meanwhile, the oil is poured into the oil cup by means of the pipette, until the extreme point of the indicator just projects above the surface of the liquid. It is important that this limit should not be exceeded, but if this should happen, the cup must be emptied, dried carefully, and refilled. Any bubbles forming on the surface of the oil must be dissipated by pricking with the warm charred point of a burnt-out match. The table on which the cup stands during the operation of filling, should be perfectly horizontal and quite near to the water bath, to minimise the risk of tilting or shaking the cup. The oil is poured into the centre of the cup and not against the sides, and to prevent bubbles, the nozzle of the pipette should be kept below the surface of the liquid. The utmost exactness is obtained by slowly adding the oil by a pipette until the point of the indicator is just *about* to disappear under the surface of the liquid, and then removing the excess by the insertion of a small pipette. Bubbles formed by emptying the cup may be removed on refilling, by a warm metallic point or a charred match. The lid of the cup is put on directly after pouring in the oil, the thermometer being previously inserted in its socket, and pressed down tightly, avoiding contact between the ebonite plate under the clockwork and the knobs, K, on the bath, as this would prevent the lid from fitting properly. The insertion of the oil cup into the bath must be done without tilting or shaking, and to avoid the risk of this, the cup, previously cooled by ice and water to 8° C. (to prevent the oil getting warm while filling), may be put into position before filling. Should the water bath be at a higher temperature than 54° to 55°, it must be cooled by the addition of cold water, and when that degree is reached, the lamp is extinguished.

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[1] *Vorschriften betreffend den Abelschen Petroleumprober und seine Anwendung*, Berlin, 1883.

When the oil approaches the temperature at which the first test is to be applied, in accordance with the foregoing table, the test lamp is lighted and the flame adjusted until, when viewed from the front, it is

TABLE LXI.—CORRECTION OF APPARENT FLASHING POINTS TO THE NORMAL BAROMETRIC PRESSURE OF 760 MILLIMETRES.

MILLIMETRE-PRESSURE.																				
685	690	695	700	705	710	715	720	725	730	735	740	745	750	755	760	765	770	775	780	785
Flashing Points, Centigrade Scale.																				
16·4	16·6	16·7	16·9	17·1	17·3	17·4	17·6	17·8	18·0	18·1	18·3	18·5	18·7	18·8	19·0	19·2	19·4	19·5	19·7	19·9
16·9	17·1	17·2	17·4	17·6	17·8	17·9	18·1	18·3	18·5	18·6	18·8	19·0	19·2	19·3	19·5	19·7	19·9	20·0	20·2	20·4
17·4	17·6	17·7	17·9	18·1	18·3	18·4	18·6	18·8	19·0	19·1	19·3	19·5	19·7	19·8	20·0	20·2	20·4	20·5	20·7	20·9
17·9	18·1	18·2	18·4	18·6	18·8	18·9	19·1	19·3	19·5	19·6	19·8	20·0	20·2	20·3	20·5	20·7	20·9	21·0	21·2	21·4
18·4	18·6	18·7	18·9	19·1	19·3	19·4	19·6	19·8	20·0	20·1	20·3	20·5	20·7	20·8	21·0	21·2	21·4	21·5	21·7	21·9
18·9	19·1	19·2	19·4	19·6	19·8	19·9	20·1	20·3	20·5	20·6	20·8	21·0	21·2	21·3	21·5	21·7	21·9	22·0	22·2	22·4
19·4	19·6	19·7	19·9	20·1	20·3	20·4	20·6	20·8	21·0	21·1	21·3	21·5	21·7	21·8	22·0	22·2	22·4	22·5	22·7	22·9
19·9	20·1	20·2	20·4	20·6	20·8	20·9	21·1	21·3	21·5	21·6	21·8	22·0	22·2	22·3	22·5	22·7	22·9	23·0	23·2	23·4
20·4	20·6	20·7	20·9	21·1	21·3	21·4	21·6	21·8	22·0	22·1	22·3	22·5	22·7	22·8	23·0	23·2	23·4	23·5	23·7	23·9
20·9	21·1	21·2	21·4	21·6	21·8	21·9	22·1	22·3	22·5	22·6	22·8	23·0	23·2	23·3	23·5	23·7	23·9	24·0	24·2	24·4
21·4	21·6	21·7	21·9	22·1	22·3	22·4	22·6	22·8	23·0	23·1	23·3	23·5	23·7	23·8	24·0	24·2	24·4	24·5	24·7	24·9
21·9	22·1	22·2	22·4	22·6	22·8	22·9	23·1	23·3	23·5	23·6	23·8	24·0	24·2	24·3	24·5	24·7	24·9	25·0	25·2	25·4
22·4	22·6	22·7	22·9	23·1	23·3	23·4	23·6	23·8	24·0	24·1	24·3	24·5	24·7	24·8	25·0	25·2	25·4	25·5	25·7	25·9

of the same width as the white bead on the lid. This is important, as the size of the flame has an influence on the flashing temperature. The clockwork is then wound up by turning the milled head as far as it will go in the direction indicated by the arrow. On releasing the catch by pressing on the trigger, the slide slowly and regularly moves aside, and at the end of two seconds has returned to its original position. During the movement of the slide, the behaviour of the test-flame as it approaches the surface of the oil must be carefully observed, particular attention being directed to sheltering the apparatus from all draughts and from the breath of the operator. This is facilitated by the provision of a glass plate fixed to the draw-out side of the case containing the apparatus. The test is to be repeated at every ½° rise of the thermometer until a flash is obtained. Before the absolute flashing point is reached, the size of the test-flame will be observed to increase by a kind of halo when dipped towards the oil, but the true flash is a bluish, lightning-like flame extending over the whole free surface of the oil. The temperature indicated by the thermometer is subject to correction, both as regards barometric pressure and error, if any, of the thermometer itself, according to the variation ascertained on standardising the instrument. The test is repeated with a fresh portion of the same oil, after cooling the oil cup and lid, drying and freeing them, as well as the thermometer, from all adherent drops of oil, and reheating the bath to 55° C.

If the result of the second test agrees with the first within ½°, the average is taken as the apparent flashing point. If, however, the difference is 1° or more, a third test is necessary; and provided the results of the three do not differ more than 1½°, the average is taken. In case of a greater divergence, a fresh set of tests must be made. In the case of oils flashing at the first application of the test-flame, the actual flashing point may be higher than is indicated by the thermometer, the accumulation of vapour in the oil cup causing the flash to occur sooner than it would under ordinary circumstances. If it is desired to accurately test such oils, the operation is begun at a lower temperature than usual, and repeated at lower degrees until no flash is produced on first opening the slide.

The apparent flashing points must be corrected for pressure, according to Table LXI., by finding the observed flashing point in the column headed by the existing height of the barometer, and proceeding in the same row to the column headed 760, which will show the actual flashing point at normal pressure. Fractions between the figures given in the table are to be counted as the figure to which they most nearly approach. Any error recorded by the standardiser of the apparatus must be corrected before applying the correction in the table.

The Standardising of the Abel-Pensky Instrument.—By an order of the Imperial Chancellor, dated 21st July, 1882, the *Kaiserliche Normal-Aichungs-Kommission* was empowered to standardise and stamp instruments for testing petroleum, particular attention being devoted to the following points:—

(*a*) The dimensions of the apparatus.
(*b*) The accurate timing of the slide movement.
(*c*) The accuracy of the thermometer.
(*d*) The correctness of the flashing points indicated by the apparatus.
(*e*) The accuracy of the metallic barometer supplied with the instrument.

The examination of the thermometers should not take place until they have been delivered.

In verifying the dimensions of the apparatus, the following variations from the exact standard are allowed in:—

	Millimetres.
The thickness of the metal plates,	0·2
The diameter of the lamp spout,	0·2
The distance of the point of the filling indicator from the upper edge of the cup,	0·5
The distance from the lower corner of the inside of the lamp spout to the upper face of the cup lid when the lamp is fully tipped,	0·5
The thickness of the ebonite ring,	0·5
The inside diameter and height of the oil cup; the width of the brass ring; its distance from the upper edge of the cup; the distance of the axis of the slide from the centre of the cup lid and the centre of the three apertures; the diameter of the bead; and the dimensions of the tube for the insertion of the thermometer, t_1,	1·0
The distance of the centre of the bulb of the thermometer, t', from the end of the sheathing tube and from the underside of the cup lid,	1·0
The dimensions of the water bath, and of the outer cylinder; the width of the ebonite ring on the bath; and the distance of the lowest mark on the scale of either thermometer from the enlargement on the tube,	2·0

The variation of time allowed for the slide movement is 0·2 second over or under the prescribed standard. The thermometer, t_1, may not vary from the normal instrument more than 0·2° C. when tested in four places on the scale, and the thermometer, t_2, not more than 0·5° C. when tested in two places. Furthermore, successive portions of the same sample of oil, consecutively examined, should not show a greater divergence of flashing point than 0·75° C., and the average of five or seven such tests should not differ from the average of the same recorded by the standard by more than 0·5° C., an oil approximating to the standard flashing point being used for the experiment. The metallic barometer belonging to the apparatus should not differ more than 2 millimetres from the standard at the ordinary room temperature. It must be examined with a view to ascertaining the influence of sudden alterations of pressure or continued shaking of the instrument on its accuracy between the limits of 680 and 790 mm. The instruments which satisfy the tests imposed, are stamped by the Normal-Aichungs-Kommission on all the removable portions, and the amount of variation or error of flashing point to be allowed for is indicated. The maker's name, the number of the instrument, and the year of examination are included in the stamping, and all the particulars are inscribed on a certificate issued by the standardiser, together with the following measurements:—

(*a*) Distance of the point of the filling indicator from the upper edge of the oil cup.

(*b*) Distance of the lowest inside point of the lamp spout from the under surface of the cup lid when the lamp is fully tilted.

(*c*) Distance of the central point of the oil-thermometer bulb from the under surface of the cup lid.

To guard against any alteration on these points subsequent to standardising, the Aichungs-Kommission send out with each apparatus examined, a stamped gauge consisting of a rectangular steel plate, on one side of which is a projection for controlling the measurement, *a*; on another a second projection bounded by two flutings, to measure, *b*, and furnished with a projecting stud on one of its flat surfaces for gauging, *c*. To examine *a*, the gauge is applied to the edge of the oil cup so that the projection hangs down inside and the mark on it is touched by the point of the filling mark. For the second verification, *b*, the clockwork is set in motion, and the apertures in the lid are wedged open so that the mouth of the lamp is at its lowest point. The gauge is then applied under the lid, and the lower inside corner of the spout should coincide with the end of the smaller projection. For examining *c*, the side of the gauge opposite to the smaller projection used for *b* is applied to the under side of the lid, when the stud should exactly touch the middle of the bulb of the thermometer. The length of the lamp spout can also be verified, a mark cut at right angles to the plain side of the gauge showing the exact size. The edge of the spout mouth should coincide with the mark; and should either the top or bottom corner fail to do so, the apparatus is out of adjustment.

Braun's Modification.—In 1882, Braun of Berlin patented the application of a magnetic pendulum arrangement for applying the test flame in the Abel apparatus.

The Use of a Stirrer in the Oil Cup.—In 1881, Engler and Haas made a number of experiments with the Abel and other instruments, and came to the conclusion that the provision of a stirrer in the oil cup was desirable. Victor Meyer had previously expressed the same opinion. In the Abel apparatus, a stratum of vapour is formed upon the surface of the oil, and the temperature of the oil is not uniform throughout. It is, therefore, necessary that the dimensions of the air space above the oil, the depth to which the test-flame is inserted, the size of the orifices in the cover, the position of the thermometer bulb, and other particulars should be defined with greater accuracy than would probably be necessary if a stirrer were added; but experience has shown that the Abel instrument can be readily standardised, and any number of instruments can thus be constructed to give concordant results if used with a reasonable amount of care. The addition of a stirrer, both for the vapour and for the oil, is no doubt desirable when the Abel instrument in its original or modified form is applied to the testing of oils of high flashing point, such as lubricating oils, but Dr. Engler and Dr. Bunte have expressed to the author their concurrence in his view that it is not requisite when the instrument is employed in testing kerosene.

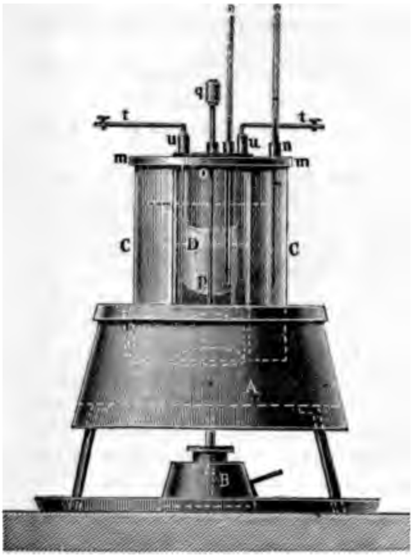

Fig. 209.

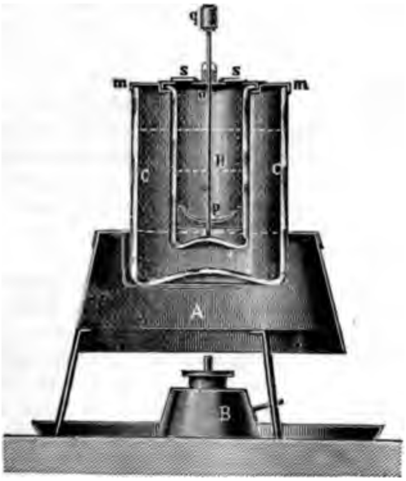

Fig. 210.

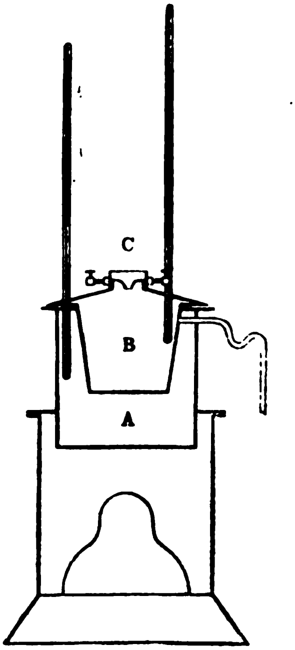

Fig. 208.

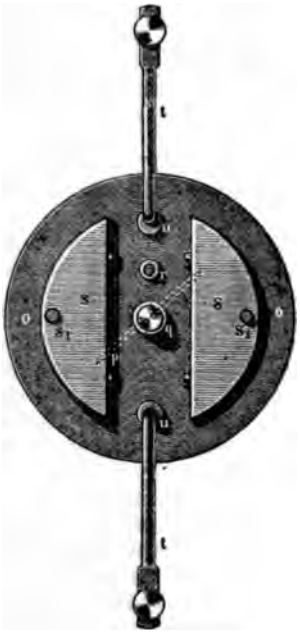

Fig. 211.

Letheby's Electric Tester.—In addition to the Saybolt electric tester, several others in which ignition of the oil vapour is produced by an electric spark are and have been in use. As early as 1870 the author saw a closed tester with an electric spark igniting arrangement, in use by the late Dr. Letheby in the laboratory of the London Hospital. The oil cup was of glass, and had a hinged metal cover which was blown open on ignition of the vapour.

Pease's Electric Tester.—In Pease's closed tester (Fig. 208), the vapour is ignited by an electric spark passing between wires, C, above the oil in the cup, B, which rests in a water bath, A.

Engler's Electric Tester.—In Dr. Engler's closed cup electric tester[1] (Figs. 209 to 211), the copper water bath, A, which is heated by a lamp, B, is 15 centimetres in diameter at the top, 18 at the bottom, and 15 centimetres high, including the feet. It carries a perforated plate, 4 centimetres from the top, supporting a cylindrical glass water bath, C, 10 centimetres wide and 12 to 14 centimetres high. The bath, C, which has a mark to indicate the proper height of the water, and is provided with a lid, *m*, and a thermometer, *n*, contains the glass oil cup, D, 10 centimetres high and 5½ centimetres in internal diameter. The oil cup has a lid, *o* (Fig. 211), which is not fixed very tightly, in order that it may be blown off without injuring the apparatus in case of an unusually strong explosion. It has a stirrer, *p*, with a handle, *q*, and a thermometer, *r*, and is further fitted with two wires, *t*, *t*, connected with an induction coil and terminating, inside the cup, in platinum points 1 millimetre apart and from ½ to ⅔ centimetre above the surface of the oil. Ebonite insulators, *u*, prevent short-circuiting through the lid, *o*. A chromate battery and small induction coil capable of producing sparks from 2 to 3 millimetres in length are used. Hinged flaps, *s*, cover openings in the lid, *o*.

Directions for Use.—In testing an oil, the water baths are filled with water, and the oil cup to a mark with the oil. When the oil cup is in place, the water in the bath, C, reaches to within 1 centimetre of the top. The spirit lamp being lighted, the temperature of the oil gradually rises, a rapid increase of temperature being prevented by the use of the two water baths, so that the size of the heating flame makes little difference in the rate of progression. The difference between the water and oil thermometers should not exceed 5° C. At about 20° C., the spark is passed, during ½ to 1 second, and this is repeated at each rise of 1° until the flashing point is reached, when the explosion produced blows open the hinged flaps, *s*, *s*. A few precautions are necessary to ensure accuracy. Between the applications of the spark, the stirrer should be rotated a few times, but very carefully in order to avoid splashing the platinum electrodes. When the apparatus is used several times in succession, fresh water must be poured into the upper water bath, refilling of the lower bath being unnecessary, as not affecting the results. If a difficulty is experienced in getting the spark to pass freely, this is generally found to be due to one of two causes. Either the apparatus has been brought from a cold to a warm room, and a deposit of moisture has occurred on the electrodes, which can be removed by standing the instrument in a warm place for a short time; or the points have become dirty from constant use, in which case they must be cleaned with sand-paper or a file. The current should be strong enough to give a good spark when the points are 1 mm. apart, but not so powerful as to short-circuit through the metallic lid of the apparatus.

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[1] *Zeits. f. anal. Chemie*, 1881, xx., 27, and Post's *Chemisch-technische Analyse*, ii., 299.

Heumann's Modification.—In a modification of the Engler instrument introduced by Heumann, the stirrer acts upon the vapour in the oil cup as well as upon the oil,[1] and a gas flame is substituted for the electric spark. The following is a description of the apparatus:—In Fig. 212, *a* is a glass oil cup, with a base, *g*, forming a support for the stirrer; *b*, the metal water bath; *c*, the stirrer; *t*, the thermometer; and *d*, the test-flame. This flame is supplied with gas at *k*, through an upright tube, *i*, and can be brought into contact with the oil vapour by depressing the tube. On being released, the tube is returned to its former position by the action of a spring, *f*. The cup lid is fitted with hinged flaps, as in the Engler instrument. The test-flame is applied at each degree until the lid-flaps are thrown open by the flash. Results agreeing within ½° C. are obtained.

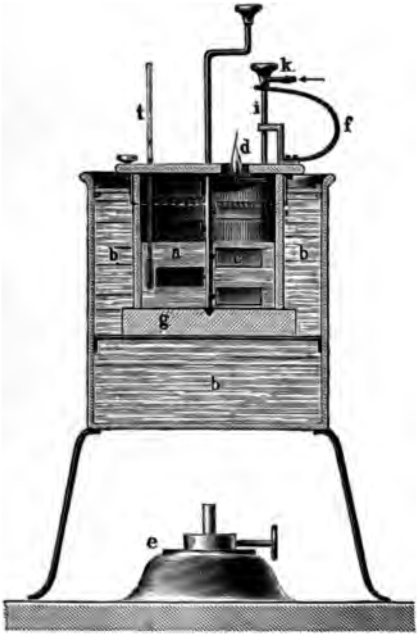

Fig. 212.

Victor Meyer's Instrument.—In Victor Meyer's method of determining the flashing point, the oil is contained in a corked cylinder which is placed in a water bath. When the expected flashing point is approached—the temperature being indicated by a thermometer passed through the cork—the cylinder is removed, quickly shaken, allowed to stand until the froth has broken, then opened, and a small gas flame applied to the mouth. If the mixture of air and oil vapour explodes, the experiment is repeated at lower temperatures, with 1° C. difference between the tests. If no explosion occurs, the experiment is similarly repeated at higher temperatures.

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[1] *Die Chemische Industrie*, 1884, vi., and Post's *Chemische-technische Analyse*, 1888, ii., 501.

Haas's Modification.—An improvement on Victor Meyer's method, introduced by Haas, has been described.[1] The oil cup is a vertical glass cylinder with a hinged copper lid. A knob fixed in the lid is traversed by a capillary channel, to relieve the internal pressure. Two platinum wires passing through the sides of the cup, and separated at the terminals by a distance of 1 millimetre, are connected outside the cup, with two copper wires passing to metal plates on opposite sides of the bottom of the cup. To ensure a constant temperature, the oil cup is enclosed in an outer cylinder resting on the base of the oil cup, and fastened above by catches in a sliding ring. The heat is applied by an air bath having an earthenware cover, and fitted with a rack-work arrangement for raising and lowering the oil cup to vary the temperature. A chromate battery is used, and the arrangements are such that connection is made by placing the oil cup with its bottom plates on a pair of terminals.

Directions for Use.—The oil cup is filled up to the mark with the oil to be tested, and, enclosed in its jacket, is placed in the previously warmed air bath. The temperature is then caused to rise gradually, by adjusting the lamp and the depth of immersion of the oil cup in the air bath, so that the difference between the air and oil thermometers is only 5° C. at most. When the requisite temperature is attained, the oil cup, with its jacket, is removed, shaken about ten times (closing the hole in the knob with the finger), and placed on the terminals, the temperature being noted. After waiting for the bubbles to subside, and another minute for the spray to settle, contact is made and the spark passed during one second. The process is repeated until the lid is thrown open by the occurrence of an explosion. Experiments show that variations in the rate of heating, the strength of the current, and the length and duration of the spark, only affect the results when carried to extremes. The size of the instrument, the quantity of oil, and the distance of the platinum points from the surface of the oil, are also without effect on the results.

The Abel instrument was by no means the first close-test apparatus devised, but it has been convenient to consider both it and certain other forms, in describing the development of petroleum legislation in this country and on the Continent.

Tagliabue's Closed Tester.—As early as 1862, Tagliabue patented in America a "coal-oil pyrometer," for use either as a closed cup to determine the flashing point, or as an open cup for ascertaining the igniting point of the oil. The apparatus is shown in Figs. 213 and 214, the upper portion of Fig. 214 showing the cover of the instrument illustrated in Fig. 213, while the larger illustration in Fig. 214 shows a simpler form of the apparatus. The cylindrical water bath is supported by a metal stand having an aperture near the bottom for the introduction of a small spirit lamp. The vapour disengaged from the oil by the application of heat, mixes with atmospheric air admitted through perforations in the lid, and an explosive mixture is thus formed, which ascends into the dome. The flashing point of the oil is ascertained by the insertion of a lighted taper or match into an opening in the dome, at intervals, until a slight explosion occurs. To determine the igniting point of the oil, the cup is opened by partially revolving the cover, and the test-flame is held for one or two seconds in contact with the escaping vapour.

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[1] *Zeits. f. anal. Chemie*, 1880, xx., 29.

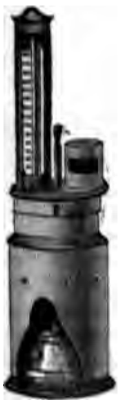

Fig. 213.

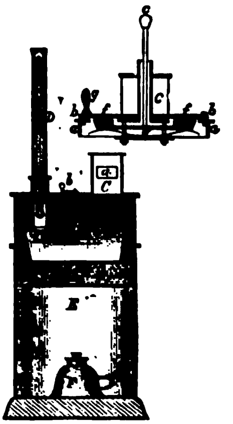

Fig. 214.

Directions for Use.—Remove the cover, *a*, of the instrument by turning it until the vertical slots come into position to allow of its being taken off, take out the oil cup, fill the outer vessel with water to a distance of within 2 inches from the top, replace the oil cup and fill it with the oil to be tested to within $\frac{3}{8}$ inch from the top, replace and secure the cover in position, supply the lamp with alcohol and trim the wick to give a small flame, light it and place it under the water bath. The mercury in the thermometer will soon begin to rise; watch this carefully until it approaches to within about 20° of the temperature at which the oil is expected to flash, remove the lamp, press down the brass knob, *c*,[1] which will open the valves and allow air to enter into the instrument and vapour to rise in the dome, C. Into the aperture of this insert a very small lighted taper, and if the vaporising point has been reached, a slight "puff" will occur; if this should not take place, replace the lamp and allow the mercury in the thermometer to ascend very slowly, 2° or 3° per minute; remove the lamp and perform the same operation with the lighted taper until the slight "puff" is produced; proceed very slowly with this operation, and when the "puff" occurs, take a simultaneous reading of the thermometer; this indicates the flashing point. To ascertain the burning point of the oil, replace the lighted lamp and allow the thermometer to rise about 8°; now remove the lamp, swing back the cover by means of the handle, *g*, and pass the lighted taper quickly across the oil without inclining the taper downwards; if the burning point has been attained, the oil will ignite; if not, cover the oil and replace the lamp, watching the thermometer carefully, and not allowing the mercury to rise more than 3° or 5° between the tests. When the oil takes fire, read the thermometer, and this will give the igniting point. It is advisable in all cases to make more than one test of the oil; in each new test the water and oil should be changed, and the instrument allowed to cool.

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[1] This knob is connected with a bar, *e*, the ends of which normally cover apertures, *f*, in a pivoted plate, *b*. The plate may be moved by means of a handle, *g*, when it is desired to open the cup. The bar, *e*, is supported by a spring.

Having learned the vaporising point in the first operation, in the succeeding ones the instrument can be more carefully watched, and probably the flashing point recorded will be lower than in the first operation. When "high grade" oils are being tested, sand is placed in the outer vessel instead of water. The author has not found it possible to obtain concordant results with this instrument. In some cases, the results closely agree with those furnished by the Abel apparatus, but in most instances, they appear to be from 6° to 8° F. higher, and occasionally 10° or 12° higher. This apparatus was formerly used in Germany.[1] The simpler form of the instrument shown in Fig. 214 consists of a water bath, A; an oil cup, B; the hood, C, with an opening, *a*, into which the test-flame is inserted; the body, E; the thermometer, D; the lamp, F; and the pivoted cover, *b*, over the air-inlet.

Wisconsin Tester.—The instrument officially employed in the State of Wisconsin, has a copper oil cup with a copper cover in which there is a small opening for the insertion of the test-flame.

Elliott Tester.—In 1882, the State Board of Health of New York adopted a form of the tester last described, embodying improvements suggested by Professor Arthur H. Elliott, the chief of which was the substitution of a glass for a metal cover. The following is the official description of the apparatus and of the mode of applying the test:—

The instrument consists of a sheet-copper stand 8½ inches high, exclusive of the base, and 4½ inches in diameter. On one side is an aperture 3⅛ inches high, for introducing a small spirit lamp about 3 inches in height, or better, a small gas burner in place of the lamp, when a supply of gas is at hand. The water bath is also of copper, and is 4⅛ inches in height and 4 inches inside diameter. The opening in the top is 2⅞ inches in diameter. It is also provided with a ¼-inch flange which supports the bath in the cylindrical stand. The capacity of the bath is about 20 fluid ounces, this quantity being indicated by a mark on the inside. The lower portion of the copper oil holder is 3⅜ inches high and 2¾ inches inside diameter. The upper part is 1 inch high and 3⅜ inches diameter, and serves as a vapour chamber. The upper rim is provided with a small flange which serves to hold the glass cover in place. The oil holder contains about 10 fluid ounces when filled to within ⅛ of an inch of the flange which joins the oil cup and the vapour chamber. In order to prevent reflection from the otherwise bright surface of the metal, the oil cup is blackened on the inside by forming a sulphide of copper by means of sulphide of ammonium. The cover is of glass, and is 3⅝ inches in diameter; on one side is a circular opening, closed by a cork through which the thermometer passes. In front of this is a second opening ¾ of an inch deep and the same in width on the rim, through which the flashing jet is passed in testing. The substitution of a glass for a metal cover more readily enables the operator to note the exact point at which the flash occurs. A small gas jet, ¼ inch in length, furnishes the best means for igniting the vapour. Where gas cannot be had, the flame from a small waxed twine answers very well. The test shall be applied according to the following directions:—

Remove the oil cup and fill the water bath with cold water up to the mark on the inside. Replace the oil cup and pour in enough oil to fill it to within ⅛ of an inch of the flange joining the cup and the vapour chamber above. Care must be taken that the oil does not flow over the flange. Remove all air bubbles with a piece of dry paper. Place the glass cover on the oil cup, and so adjust the thermometer that its bulb shall be just covered by the oil. If an alcohol lamp is employed for heating the water bath, the wick should be carefully trimmed and adjusted to a small flame. A small Bunsen burner may be used in place of the lamp. The rate of heating should be about 2° per minute, and should in no case exceed 3°. As a flash torch, a small gas jet ¼ inch in length should be employed. When gas is not at hand, employ a piece of waxed linen twine. The flame in this case, however, should be small. When the temperature of the oil has reached 85° F., the testings should commence. To this end, insert the torch into the opening in the cover, passing it in at such an angle as to well clear the cover, and to a distance about half-way between the oil and the cover. The motion should be steady and uniform, rapid and without any pause. This should be repeated at every 2° rise of the thermometer until the temperature has reached 95°, when the lamp should be removed and the testings should be made for each degree of temperature until 100° is reached. After this, the lamp may be replaced if necessary, and the testings continued for each 2°. The appearance of a slight bluish flame shows that the flashing point has been reached. In every case, note the temperature of the oil before introducing the torch. The flame of the torch must not come in contact with the oil. The water bath should be filled with cold water for each separate test, and the oil from a previous test carefully wiped from the oil cup. The instrument to be used in ascertaining the igniting point of oils shall consist of the cylinder, the copper oil cup, together with a copper collar for suspending the cup in the cylinder, and an adjustable support for holding the thermometer. The test for ascertaining the igniting point shall be conducted as follows:—Fill the cup with the oil to be tested to within ⅜ of an inch of the flange joining the cup and the vapour chamber above. Care must be taken that the oil does not flow over the flange. Place the cup in the cylinder and adjust the thermometer so that its bulb shall be just covered by the oil. Place the lamp or gas burner under the oil cup. The rate of heating should not exceed 10° a minute below 250° F., nor exceed 5° a minute above this point. The testing-flame described in the directions for ascertaining the flashing point should be used. It should be applied to the surface of the oil at every 5° rise in the thermometer, till the oil ignites.

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[1] *Zeits. f. anal. Chemie*, 1881, xxi., 15.

An inconveniently large quantity of oil is required for this test, and, according to the author's experience, the results obtained, while not differing greatly from those furnished by the Abel instrument, are less concordant.

Granier's Tester.—The first "automatic" tester introduced was that of Granier, which has for many years been officially employed in France, and is thus described.[1] The apparatus consists of a small copper cup divided into two concentric parts, the walls of the inner division being conical. In the aperture at the apex of the cone is inserted a tubular wick on a small mandrel which stands in a depression formed in the bottom of the cup, so as to be perfectly upright. There is a small tube in the outer division to serve as a gauge for the quantity of oil, and as an overflow pipe to carry away any slight excess. Heat is applied to the oil, not by a lamp below, but by means of a bent copper wire fixed in the aperture of the lid, so as to receive heat from the test-flame and convey it to the oil, into which its two ends dip. The cover has a circular opening over the test-flame, with a small lid also pierced by a central aperture.

Directions for Use.—The method of applying the test as prescribed by law is as follows:—The apparatus must be clean, and the wick must be renewed if carbonised to a depth exceeding 1 mm. The wick, fixed upon its metallic mandrel, is placed in the metallic cone in the cup, so as to rest evenly on the bottom of the cup. The oil to be tested, the temperature of which should not exceed 25° C., is poured into the cup in such a manner that it runs into the wick, the cup being filled to the top of the connecting tube. The cover is then placed on the cup, the small lid in the centre of the cover closed, and the thermometer placed in its socket. To ascertain the degree of inflammability, a lighted match is held near the small orifice in the centre of the small lid, and kept there for several seconds, and the temperature at which a petroleum vapour flame appears and remains above the orifice is carefully noted. If a persistent vapour flame is not obtained, the wick should be lighted at several points, so as to produce combustion all round the edge, and the small lid closed. The rise in temperature is to be carefully observed, the degree at which a slight explosion occurs and extinguishes the flame being the degree of inflammability. Should this be either 32°, 33°, or 34° C., the operation is to be twice repeated with fresh portions of the sample, and the average of the three taken as the correct result. Liquids passing the test of 35° C. are considered as of the second class, and those failing to do so are held to belong to the first class, of inflammable liquids.

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[1] *Bull. Soc. l'Ind. Nat.*, 1873, 401.

The directions issued by the maker of the Granier cup are as follows:—To ascertain the flashing point, the oil is poured carefully into the central cone surrounding the wick until the outer division is full to the level of the overflow pipe. The wick should project not more than 1 mm. above the apex of the cone. After putting on the cover of the cup, a light is applied to the central orifice, when, if the oil disengages vapour at a lower temperature than the surrounding air, a flash is immediately obtained. In all cases where no flash is observed, the wick is lighted, the small lid on the cover is shut down, and the apparatus is kept in a still atmosphere. The small wire placed over the flame conducts heat to the oil, and when the temperature reaches the point at which inflammable vapour is evolved, a flash occurs at the orifice in the lid, putting out the light. To determine the density of the oil, a specific gravity instrument is supplied with the tester, graduated in degrees of 2½ grammes per litre at a standard temperature of 15° C. This is a preliminary test, and obviates the necessity of the flash test in the case of oils lighter than 0·760, these always taking fire below 0° C. The standard of density in France is 0·800 for petroleum, and 0·815 for shale oil.

The author has made a considerable number of tests with the Granier apparatus, but has found the action so unsatisfactory that he is unable to state how the results compare with those given by the Abel instrument.

Parrish's "Naphthometer."—In Parrish's naphthometer, an "automatic" tester which has been largely used in Holland,[1] the cover of the oil cup is provided with a wick holder, fixed centrally in a short tube of greater diameter, and carrying a lamp wick which passes down into the oil. The oil thermometer is inserted in a tube which is attached to the cover of the cup. This tube communicates (1) with the external air through orifices in the cup at the upper end, (2) with the air in the upper part of the oil cup through a lateral aperture, and (3) with the oil in the cup through openings in the bottom of the tube. A screen prevents the heat of the test-flame from affecting the thermometer. The oil cup fits in a water bath which is placed in an outer casing containing the spirit lamp for heating the apparatus. In applying the test, cold water is poured into the water bath, and the oil cup is filled to within 1 centimetre from the top. The flame of the spirit lamp is regulated to a length of 1 to 1½ centimetre, and the testing flame should not exceed 6 or 7 millimetres in length. The heat from the latter causes a current of air to pass down the tube containing the thermometer, over the surface of the oil, where it mingles with the oil vapour, and to issue near the test-flame, ignition occurring when the flashing point of the oil is reached.

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[1] *Zeits. f. anal. Chemie*, 1881, xx., 21.

The Parrish-Engler Naphthometer.—Parrish's instrument having been found by Engler and Haas[2] to give variable results according to the rate of heating, the size of the test-flame, and the degree of shelter from draughts afforded to the flame, an improved form was devised by Engler; an air space between the water bath and the oil cup being provided as in the Abel tester, and an ebonite ring interposed to prevent contact at the top. A glass chimney supported on a swing bracket can be brought into position over the test-flame. The lid of the oil cup is fitted with a slide, by means of which the ventilating and testing apertures may be closed or opened. The air entering the cup is directed over the surface of the oil by a semicircular screen, attached to the under surface of the lid and extending below the surface of the oil. This screen is pierced with holes for passage of the air. The correct heights of the heating- and test-flames are indicated by small wires projecting from the upper surface of the lamp and the test cylinder respectively.

The water bath is completely filled, and the oil to be tested is poured into the oil cup up to the level of the indicator. The oil cup lid being fastened in position, the glass chimney is turned so as to enclose the test cylinder, the heating lamp is lighted, and when the thermometer indicates an approach to the anticipated flashing temperature, the test lamp is also lighted. The slide is then withdrawn for five seconds and quickly returned. This is repeated every degree until flashing occurs. The apparatus is stated to give good results even in the hands of unskilled operators, provided the proper quantity of oil and the time named for opening the slide are correctly observed.

The Phlog-elaio-mètre.—The instrument sold under this name has been officially adopted by the City of Marseilles. It is described by the maker as consisting of a water bath heated by a spirit lamp, and a covered oil vessel fitted with a thermometer. At the side of the thermometer, there is a small chimney furnished with a wick of two or three strands of cotton, and near this there are two openings in the cover which are closed by a latch. The following are the directions for use:—Fill the water bath to the horizontal line marked

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[1] *Zeits. f. anal. Chemie*, 1881, xx., 23.

so that the level of the water is a little below the two overflow openings when the oil cup has been inserted. The oil vessel is to be filled with the oil to be tested up to the level of a horizontal ring which is fixed in it, and the lower part of the thermometer is to be passed through this ring. The wick in the chimney must pass into the oil, and should be cut off close at the top. Open the latch, light the heating lamp, regulating the flame so that the temperature of the water may be raised very slowly. When the thermometer begins to rise, light the wick in the little chimney, and watch the thermometer. When the flashing point is approached, the test-flame begins to flicker and is finally extinguished, the temperature indicated by the thermometer when this occurs, being the flashing point of the oil.

The Foster Automatic Tester.—The Foster automatic tester (Fig. 215), employed in Ohio, is similar in principle to the original Parrish's tester. In the figure, the oil cup is shown at A, the water bath at B, the body of the apparatus, forming an air jacket, at C, and the flash jet at D.

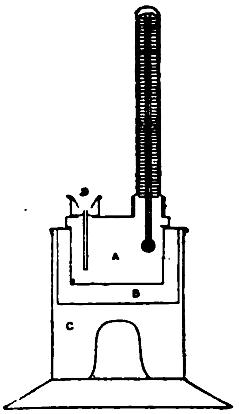

Fig. 215.

The instrument consists of a copper lamp-furnace containing a water-bath and oil cup, the latter surmounted by a closed vapour chamber, which is pierced at two points symmetrically placed for the reception of a thermometer and a flashing lamp or taper. The apparatus is elliptical in shape, the thermometer being placed in one focus of the ellipse, and the flashing taper in the other. The flashing taper consists of a small cylindrical wick holder, which is supported by radial arms attached to a ring, and rests upon a similar ring at the bottom of an open, shallow basin, the spaces between the radial arms giving egress to the oil vapour, while the wick itself extends down into the body of the oil within the cup. An inverted conical thimble, resting upon the rim of the basin, prevents the dissipation of the vapour. The thermometer is mounted in a copper tube cut away in front to expose the scale, the bulb of the thermometer, when in position, being within the body of the oil at a definite distance below the surface. A space around the tube of the thermometer, of definite diameter and distance above the surface of the oil, allows of the passage of a downward current of atmospheric air when the flashing taper is alight. An index is placed within the water bath, and within the oil cup, for maintaining uniformity in the filling of each. The heating lamp of the lamp furnace has its wick adjustable to regulate the rate of heating.

DIRECTIONS FOR USE.

1. Remove the thermometer, with its mounting, from the oil.
2. Lift off the oil cup containing the flashing taper, and half fill the open water bath with water.

3. Now take out the wick holder from the oil cup, and fill this vessel with the oil to be tested, pouring in the oil at the place of the wick holder, and noting the gauge mark at the thermometer hole—pour in the oil very gradually as the surface approaches the gauge mark. The gauge mark consists of a small pendant shelf, and the oil cup is properly filled when the upper surface of the oil just adheres to the lower surface of the gauge mark. Too much care cannot be taken at this point; therefore, having ceased pouring, tip the cup so that the oil flows away from the gauge, and then gradually restoring it to the horizontal, see that the surface again adheres, and add a little more oil if it does not.

4. See that the wick of the flashing taper be adjusted to give a very small flame—a flame that does not exceed one quarter of an inch in height. A flame that exhibits as much blue at its base as yellow at its top is right.

5. Now replace the oil cup in the water bath; return the flashing taper to its place, inverting the conical thimble around it, and return the thermometer to its place upon the cup; in doing this be sure that the casing of the latter is pushed down upon the cup as far as it will go.

6. Half fill the lamp beneath with alcohol, light it and put it in its place beneath the water bath. Now note the rate of increase in temperature as shown by the thermometer, and adjust the wick to raise the temperature at the rate of 2° per minute. When the temperature has reached 100°, light the flashing taper and observe it closely. As soon as the oil under test has reached its "flashing point," the flame of this taper will be extinguished by the "flash," and the temperature is to be noted at the instant the flame of the taper is extinguished.

Although the Foster tester belongs to the closed vessel class, the author finds that it gives results from 14° to 20° F. higher than those furnished by the Abel instrument, the extent of the difference depending upon the character of the oil.

Bernstein's Tester.—In the Bernstein tester (Fig. 216),[1] the water bath contains a cylindrical oil cup, F, which may be connected by a three-way cock, K, with either a U-tube, G, or a side tube, J, which

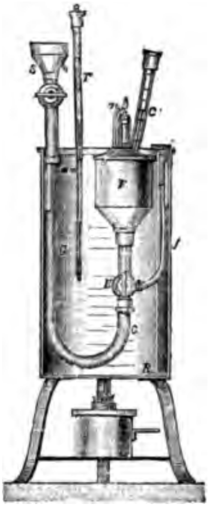

Fig. 216.

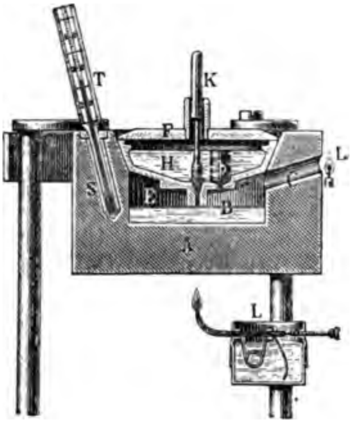

Fig. 217.

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[1] *Dingler's polytech. Journ.*, 1881, ccxl., 136.

forms a gauge to indicate the height of the oil. The lid of the oil cup is either closed by a tap at the top, or terminates in an open tube. Thermometers, T and C, are fitted in the water bath and oil cup. To apply the test, water is admitted from a reservoir, S, to the tube, G, and the pressure thus imparted to the oil expels some of the vapour from the oil cup, so that it reaches a flame, *n*. To register the flashing point, a second lamp wick is placed just above the opening where the vapour escapes, so that it may become ignited when the flash occurs. According to Engler and Haas, this apparatus gives reliable results if it is desired merely to ascertain whether a sample flashes at a given temperature or not; but if the object of testing is to ascertain the exact flashing point, too much time is occupied, and a higher result is obtained than with the average of other closed cup instruments.

The Ehrenberg Tester.—In the Ehrenberg tester, a syringe is employed to force the vapour from a closed oil chamber into contact with a flame.

Braun's Tester.—Fig. 217 represents an instrument introduced by Braun.[1] It was originally constructed of glass, the oil vapour being driven out against the test-flame by the pressure of water, but the metallic apparatus shown was afterwards employed. This consists of a steel block, A, weighing 6 kilos., the upper part, B, E, being hollowed out to a depth of 45 mm. and a diameter of 65 mm., and widened out conically at the top for the admission of a bronze cup, H. The cup has a truncated conical bottom with a downwardly projecting tube in the centre closed by a cork, fitted on a handle, K, rising up through the glass lid of the cup. A small cylinder, *b*, inside the cup, serves as a gauge, the superfluous oil running into it being removed by the aid of a pipette. The instrument rests on feet, to one of which a lamp, L, is so attached by a bracket that the flame can be brought opposite an opening, C, in the side of the block. To apply the test, oil is poured into the upper cup, H, till the level of the upper end of *b* is reached. This measured quantity of exactly 25 c.c. is then run into B, E, by raising the handle, K, and a second 25 c.c. is similarly introduced into H. The steel block being previously heated to the required degree (indicated by a thermometer, T, inserted in a boring, S, containing petroleum), the oil is allowed to remain for 3 to 5 minutes to attain the same temperature, and after a total lapse of ten minutes from the pouring in of the oil, the test-flame is applied to the passage, C, and the handle, K, raised, allowing oil to run into B, E, to displace the vapour, which is forced out through, C, against the flame. If the mixture is explosive, the flame is extinguished.

Beilstein's, Liebermann's, and Stoddard's Methods.—Beilstein,[2] Stoddard,[3] and Liebermann[4] consider that the best method of ascertaining the flashing point of petroleum is to pass a current of air through the heated oil, and observe the igniting temperature of the mixture of air and vapour evolved. Stoddard passes a continuous current, which gives less accurate results than the intermittent method pursued by Liebermann and Beilstein.

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[1] *Dingler's polytech. Journ.*, 1882, ccxliii., 476.

[2] *Zeits. f. anal. Chemie*, xxii., 309.

[3] *Berichte d. d. chem. Gesellschaft*, xv., 2555.

[4] *Zeits. f. anal. Chemie*, xxi., 321.

Beilstein's Instrument.—The last-named experimenter's instrument (Fig. 218) comprises a glass cylinder, A, 175 mm. high and 35 mm. in diameter, marked at distances of 60 and 70 mm. from the bottom, the lower mark indicating the oil level. Air is blown in through a tube, *b*, terminating in a rose, *c*. A thermometer, *t*, is used to record the temperature, its bulb being immersed to about half the depth of the oil. The apparatus is placed in a slowly-heated water bath, to produce a rise in temperature of about 1° C. in two to three minutes, and at each 1° rise, a current of air is blown in for five seconds with sufficient violence to cause a froth to rise up to the higher mark on the cylinder, a small flame being at the same time applied to the mouth of the apparatus. The first flashing point observed must be considered as a preliminary test, and the experiment must be repeated by commencing the introduction of the air current at the temperature noted. When the heating is carefully performed, the results are said to agree within ¼° C.

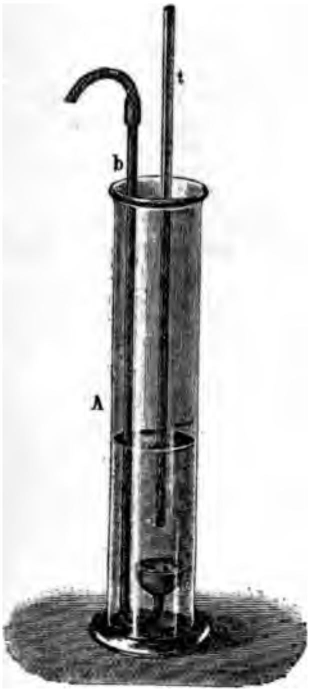

Fig. 218.

Millspaugh's Tester.—In the Millspaugh closed tester (Fig. 219), the glass oil cup is immersed only to the extent of one-tenth of its depth, in the water bath, apparently with the object of preventing overheating of the surface of the oil.

Mann's Tester.—In Mann's tester (Fig. 220), an attempt is made to reproduce the conditions existing in an ordinary petroleum lamp, the burner of the lamp being replaced by a tube fitted with a stopper which is blown out when the vapour ignites on the introduction of a light through a lateral opening.

Vette's Instrument.—An apparatus designed by Vette for ascertaining whether an oil may be safely used in a lamp whose fittings have a known conductivity and capacity for heat, rather than for determining the actual inflammability of the oil as ordinarily understood, was described in 1882.[1] A water bath fitted with a thermometer was filled with water up to an indicator point, and maintained at the required temperature, generally about 30° to 35° C. An oil vessel, fastened in the water bath by a bayonet catch, was charged with the

[1] *Dingler's polytech. Journ.*, ccxliii., 476.

oil as high as an indicator point, and was covered by a hood surrounded by a second water bath heated to 20° C., the average temperature of a room. After the apparatus had stood for fifteen minutes, the mixture of air and vapour in the hood being agitated by a stirrer, the test-flame was applied. If an explosion was produced, its effect was manifested by the lifting of a safety valve.

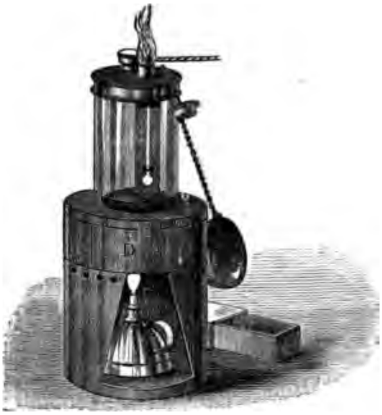

Fig. 219.

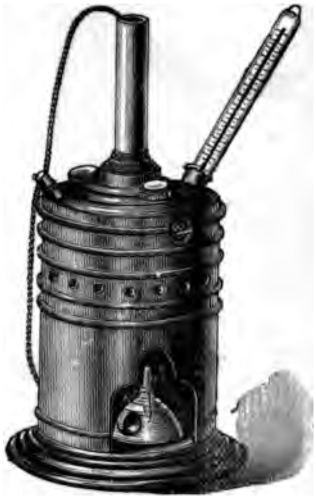

Fig. 220.

Gawalowski's Instrument.—A. Gawalowski, of Brünn, recently introduced an apparatus, which he asserts will show the degree of danger from explosion in a badly constructed lamp. In this instrument (Fig. 221), A, is the oil cup, to the lid of which is affixed a Bunsen burner, B, a safety-valve and a thermometer, T, fitted gas-tight. At the mouth of the Bunsen is soldered a hook, C, from which a thread impregnated with nitrate of ammonia passes round a pulley, and supports a lever carrying a stopper, W, placed over the central tube. On heating the oil in the receiver, and applying a light, D, to the mouth of the Bunsen burner, the flame produced when the vapour ignites destroys the thread, and allows the stopper to drop into the mouth of the central tube. The temperature at which this occurs is read off on the thermometer.

The Salleron-Urbain Tester.—In the Salleron-Urbain tester, which has been used in France in the examination of petroleum, the flashing point is deduced indirectly from the pressure exerted by the vapour evolved at a given temperature. It consists, as shown in Fig. 222, of a copper or brass vessel, A, from the bottom of which rises a conical pillar, D. The vessel is hermetically closed by a cover, *d*, which carries a guide block, C, fitting and pivoted on the pillar, D, and containing a cylindrical chamber, B, closed above by a screw stopper and indiarubber ring, *p*, and communicating below with, A, by a hole in the lid. A graduated tube of glass, *m*, 35 cm. long, and divided into millimetres; a thermometer; and a regulator consisting of a stuffing box, *l*, containing a piston raised or lowered by a screw, *r*, to adjust the pressure of water in the tube, *m*, are all fastened hermetically to the lid.

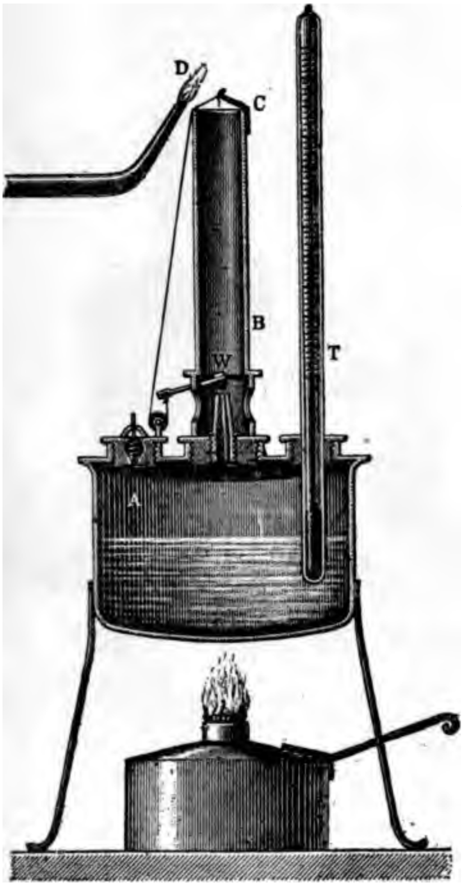

Fig. 221.

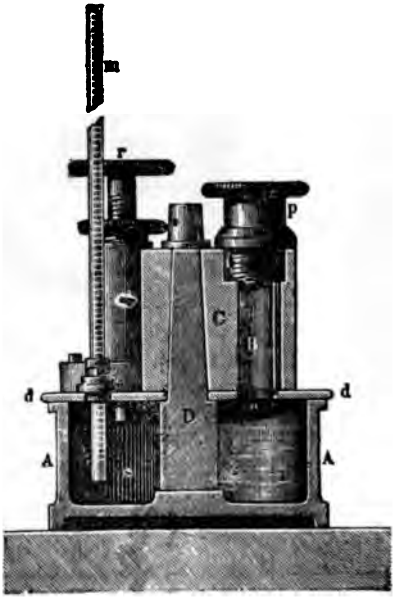

Fig. 222.

Directions for Use.—To test an oil, water is poured into the vessel, A, and the lid with its appendages is fastened down, the block, C, being so turned that the cylinder, B, is not in communication with A. The oil being placed in B, and the stopper screwed down, the whole apparatus is placed in warm water until the thermometer indicates the required temperature. The height of the column of water in *m* is reduced to 0 on the scale by turning the regulator screw, *r*, and the block, C, is turned round so as to allow the oil to flow from B into A. The heat in the vessel, A, vaporises a portion of the oil, and the pressure generated is recorded by the rise of water in the graduated tube. The inventors prepared the following table showing the pressure produced by heating a "normal petroleum" free from all constituents of less than 0·735, or more than 0·820 specific gravity[1]:—

Temperature.	Pressure expressed in Millimetres of Water in the Measuring Tube.	Temperature.	Pressure expressed in Millimetres of Water in the Measuring Tube.
°C.		°C.	
0	34·5	18	73
1	36	19	76
2	37·5	20	79
3	39	21	82·5
4	41	22	86
5	43	23	90
6	45	24	95
7	47	25	100
8	49	26	105
9	51	27	110
10	53	28	116
11	55	29	122
12	57	30	129
13	59	31	136
14	61·5	32	144
15	64	33	155
16	67	34	163
17	70	35	174

Salleron and Urbain give also the following as the determined vapour pressures (vapour tensions) of petroleum products of various densities:—

Density at 15° C.	Tension in mm. of water.	Density at 15° C.	Tension in mm. of water.
0·812	0	0·756	125
0·797	5	0·735	410
0·788	15	0·695	930
0·772	40	0·680	1,185
0·762	85	0·650	2,110

As regards this test, Engler and Haas state that the method rests entirely upon the belief that the vapour pressures vary directly with the flashing points of different varieties of petroleum, which is not in all cases correct, as the presence of a small quantity of highly volatile hydrocarbon, presumably too small in quantity to sensibly affect the inflammability, increases the pressure in the apparatus. The conclusion is, however, expressed that oils whose vapour pressure at 35° C. is not greater than is represented by a column of 64 millimetres of water, may be considered safe.

Rosenbladt's Test.—To estimate the flashing point of samples too small for use in an ordinary tester, Rosenbladt has proposed the following indirect method[1]:—

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[1] Wagner's *Jahresb. Chem. Technologie*, xii., 1866, 673.

A glass flask two-thirds full of water, is fitted with an india-rubber stopper, with two perforations, one of which is connected with a Welter's safety tube containing a little mercury, while the other carries a bent glass tube. Into a Woulf's bottle of 100 to 150 c.c. capacity are poured 12·5 c.c. (10 grammes) of the petroleum and an equal quantity of distilled water. Through the cork in one of the necks of the bottle, is passed a glass tube reaching nearly to the bottom of the bottle, where it tapers off to about 1½ millimetre diameter; the other end is in connection with the flask. The bottle is covered with a hood to prevent loss of heat, and its other neck communicates with a Liebig's condenser, delivering into a measuring glass which holds 5 to 6 c.c. and is graduated to $\frac{1}{20}$ c.c. Heat is applied to the flask until 5 to 5·1 c.c. of distillate collects in the graduated glass, and an equal quantity in a second glass after removing the first. After cooling to 15° C., the volume of oil and water is read off, and the flashing point is found by the use of the following table, which is based on experiments made with the oils mentioned:—

Petroleum flashing at °C.		Proportion of water to oil in distillate.
20	from Tagieff's works at Baku,	1 : 0·697
21		1 : 0·673
22		1 : 0·650
23		1 : 0·626
24	,, Mirzoeff's ,, ,,	1 : 0·598
25		1 : 0·572
26	,, Kokoreff's ,, ,,	1 : 0·549
27		1 : 0·526
28	,, Nobel Bros.' ,, ,,	1 : 0·504
29		1 : 0·483
30		1 : 0·464
45	,, American oleonaphtha (lubricating oil),	1 : 0·328

To obtain more reliable results, double the quantity, viz., 25 c.c. of oil may be used, in which case 10 c.c. of distillate must be collected in the first glass. Notwithstanding that the influence of variations of atmospheric pressure prevents anything like absolute accuracy, the originator of the test believes it to be correct to ± 1° C. It is recommended to distil a sample of some "normal petroleum," and make the necessary corrections for variation of pressure, from the result obtained.

Test Tube Method.—When only a small quantity of oil is available for testing, the flashing point may be approximately determined by slowly heating the oil in a test tube 4 or 5 inches in length by about three-quarter of an inch in diameter, and inserting the burning end of a piece of thin twine into the mouth of the tube at intervals, after agitating the oil. The tube should be about one-third filled with the oil, and a delicate thermometer used to take the temperature. In this way, results which do not differ materially from those furnished by the Abel instrument, may be obtained after a little practice.

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[1] *Chem. Zeit.*, 1886, x., 1587.

Comparison of Results.—In a report in 1882 to the New York State Board of Health, Professor A. H. Elliott furnishes particulars of experiments made with various testing instruments, and gives the following table of comparative results obtained with them :—

Oil used.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
	Flashing Points, ° F.										
No. 1, . .	110°	118°	120°	111°	117°	107°	103°	130°	111°	95°	119°
No. 2, . .	111°	121°	124°	115°	118°	109°	102°	128°	107°	96°	...
No. 3, . .	119°	122°	122°	112°	118°	108°	102°	130°	108°	95°	118°
No. 4, . .	97°	96°	97°	90°	93°	86°	76°	90°	81°	75°	96°

I. Tagliabue (open cup). II. Arnaboldi (open cup). III. Saybolt. IV. Tagliabue (closed cup—small). V. Tagliabue (closed cup—large). VI. Wisconsin State. VII. Abel. VIII. Bernstein. IX. Millspaugh. X. Mann. XI. Foster.

Testing for Petroleum Vapour.—The subject of the detection and measurement of petroleum vapour in the atmosphere of tanks and other spaces, has engaged the attention of the author for the past four years. He was at one time accustomed to employ an alcohol flame in testing for petroleum vapour, but becoming impressed with the importance of being provided with a delicate and thoroughly trustworthy means of determining the proportion of inflammable vapour present, he was led to investigate the subject. After experimenting with various methods of testing, with results given in a paper already referred to in the section of this work dealing with Transport and Storage,[1] the author devised, in consultation with Professor Clowes and Mr. Robert Redwood, and with the assistance of Messrs. W. J. Fraser & Co., a testing apparatus in which the hydrogen flame is employed.[2] It is well known that a non-luminous flame, burning in a space from which light is excluded, in air containing a small proportion of inflammable gas or vapour, is seen to be surrounded by a faint halo, which is termed the "flame-cap." The advantage possessed by a hydrogen flame over other flames in point of sensitiveness when thus employed as a test for inflammable gases has long been recognised, and Mr. Pieler[3] in 1883, after referring to the previous recommendation of the hydrogen flame for testing by Messrs. Mallard and Le Chatelier,[4] described an apparatus in which the gas generated in a Döbereiner lamp was burned in a specially constructed test lamp, for use in testing samples of air from the workings in coal mines. Professor Clowes is entitled to the credit of having devised a form of miners' testing lamp, which depends for its success upon the employment of hydrogen stored under pressure. In the Redwood testing lamp, compressed hydrogen is also used. This lamp and its accessories have now been in practical use for a couple of years and have been found to answer the purpose admirably.

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[1] "Redwood on the Transport of Petroleum," *Min. of Proc. Inst. C.E.*, cxvi., (1893-94), Part II.

[2] English Patent, No. 187, 1893.

[3] *Über einfache Methoden zur Untersuchung der Grubenwetter.* Aachen, 1883.

[4] *Ann. d. Mines*, 7th Ser., xix.

The complete appliances are shown in Figs. 223 and 224. They consist of the lamp, A, the reservoir of compressed hydrogen, B, and the sampling vessel, C, in which the sample of air for examination is collected. The lamp is shown in section in Fig. 224. A is the hydrogen inlet-tube with the regulating valve, B, and C is the hydrogen jet. D is the inlet-tube, for the sample of atmosphere to be tested. The bore of this tube is greatly contracted, and immediately above the point at which this tube enters the base of the lamp, is an arrangement of baffles, surmounted by three discs of wire gauze of at least 28 wires per lineal inch, or not less than 784 openings per square inch, the flow of the gaseous mixture to the flame being thus regulated, and passage of flame into the collecting vessel being prevented. The chimney, E, fits air-tight at the base, but is capable of vertical movement on an inner tube, the front of which is removed. The chimney is partly of metal and partly of glass, the metallic portion being blackened inside, and on the glass window, lines corresponding with various heights of flame-caps may be marked. The top of the hydrogen jet-tube is 10 mm. (0·4 inch) below the bottom of the window. Attached to the base of the lamp, is a telescopic support for a cloth, which envelopes the head of the observer and excludes light when the testing apparatus is used in an undarkened room. The construction of the collecting-vessel is shown in section in Fig. 224. A is the compression-pump, which is furnished with a metallic spring-piston,

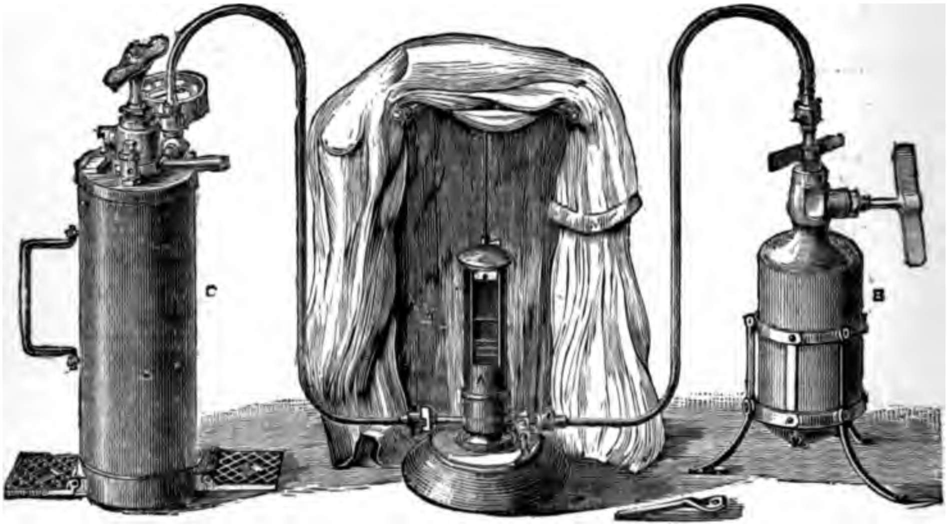

Fig. 223.

fitting the pump cylinder without the use of leather or other material, and lubricated with plumbago. Surrounding the pump is an annular space, in which the sample of atmosphere is stored. B is a collar to which may be attached a flexible suction-tube of any desired length. C is a cock, to which is connected a copper tube conveying the sample to the test lamp. The bore of this cock is very much reduced. D is a pressure gauge, and E a spring valve lifting at 30 lbs. pressure. F F are hinged brackets, on which the feet of the operator are placed while the pump is being worked. A handle is provided, by which the cylinder can be conveniently carried. The capacity of the pump is 14·84 cubic inches, and of the annular space 169·14 cubic inches, thirty double strokes of the pump being required to charge the vessel to a pressure of 30 lbs. per square inch, when it will contain $\frac{1}{8}$ cubic foot of the atmosphere sampled. It is desirable that the collecting-vessel should

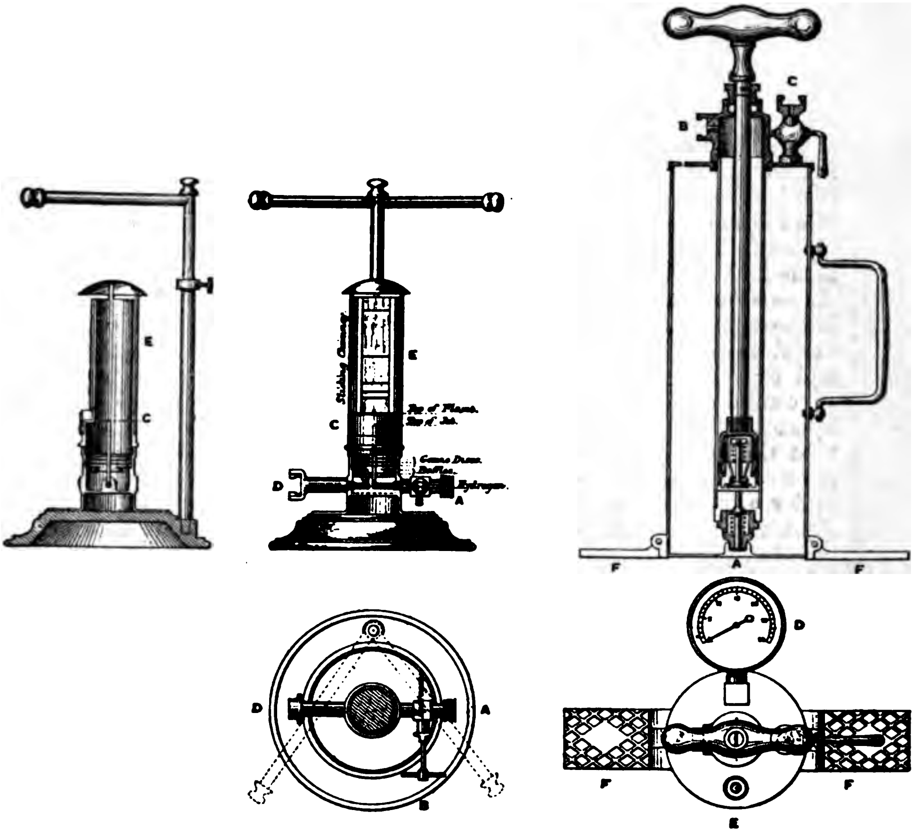

Fig. 224.

be fitted with a relief valve, as the apparatus is often used in places in which the dial of the pressure gauge cannot be easily seen. The hydrogen cylinder may be of any desired size, but the author has found that what is known as a 5-feet cylinder is of convenient dimensions. When charged to the usual pressure of 120 atmospheres, it holds enough gas to supply a 10-mm. flame for ten hours, and is quite portable. The whole apparatus may be packed into two small boxes, and may thus be readily taken on board a vessel.

In the use of the apparatus, the first step is to connect the hydrogen cylinder with the lamp, taking care that the unions are screwed up gas-tight. The sliding chimney of the lamp being raised about half way, the gas is then cautiously turned on at the cylinder, the regulating valve on the lamp being left open, and a light is applied to the hydrogen jet. The valve on the hydrogen cylinder is then adjusted so as to give a flame rather more than 10 millimetres (0·4 inch) in length, and the lamp chimney pushed down until there is an opening of only about a quarter of an inch in height at the bottom. This opening is left for the supply of air to the hydrogen flame during the few minutes occupied in the warming of the chimney. As soon as the moisture which at first condenses upon the cold glass has evaporated, the lamp is ready for use, and assuming the collecting vessel to have been already charged with the sample to be tested, and connected with the lamp, all that remains is for the observer to completely close the sliding chimney of the lamp, adjust the hydrogen flame by means of the regulating valve on the lamp, so that the tip of the flame is only just hidden when the eye of the observer is on a level with the bottom of the window, place his head under a cloth, such as used by photographers, so as to exclude light, and as soon as his eyes have become sufficiently sensitive, turn on the tap of the collecting cylinder, and carefully observe what takes place in the lamp-chimney. The tap may at once be turned on fully, as the contraction of the outlet and inlet orifices, already referred to, prevents the sudden rushing out of the contents of the cylinder, and the sample will be gradually delivered into the test lamp during a period of more than two minutes, which is ample time for noting the effect. The rate of delivery is, of course, a gradually diminishing one, but this is not found to be attended with any inconvenience, the conditions being the same in each experiment. In this way, a proportion of vapour, considerably below that which is required even for the production of an inflammable mixture, and still lower than that which is needed to give an explosive atmosphere, may be detected by the formation of a flame-cap of greyish-blue colour, which, though faint, is nevertheless easily seen, especially after a little practice. With an increase in the quantity of vapour, the flame-cap first becomes much better defined, though it is not greatly augmented in size, and then considerable enlargement of the cap occurs, this condition being arrived at before the atmosphere becomes inflammable. The author and his brother, Mr. T. Horne Redwood, have succeeded in obtaining photographs of flame-caps, which are reproduced in the frontispiece to Vol. II., and convey an accurate impression of what the observer has to look for in employing the hydrogen flame in the quantitative testing of air containing, or suspected to contain, petroleum vapour. A represents the standard hydrogen flame burning in air free from petroleum vapour, and B, C, D, E, and F show the flame-caps produced when the vapour of 0·75, 1·5, 3, 5, and 6 volumes of pentane, respectively, are mixed with 100,000 volumes of air. In each case, a hydrogen flame 10 mm. (0·4 in.) in height was employed. In taking these photographs, the lens of the camera was placed equidistant from the hydrogen flame and the sensitised plate, so as to give an image of true size. On the assumption that, in these experiments, the theoretical volume of vapour was obtained from the pentane, the proportions of vapour in the air were for B, 0·144 per cent.; for C, 0·288 per cent.; for D, 0·576 per cent.; for E, 0·96 per cent.; and for F, 1·15 per cent. Since the results given in the section on Transport and Storage (see p. 512, Table LVIII.) show that the vapour of 6·65 volumes of pentane in 100,000 volumes of air is the smallest proportion giving an inflammable atmosphere, and that this proportion must be nearly doubled to give an explosive mixture, it follows that the proportion which furnished the flame-cap, B, was about one-ninth of that necessary for the formation of a combustible mixture, and about one-eighteenth part of that which produces an explosive mixture. The test is, therefore, a delicate one; and it is obvious that, if the interior of a tank or other space be ventilated until a sample of the atmosphere gives no flame-cap with this apparatus, an ample margin of safety will be provided.

In taking a sample of the air in a tank, the collecting vessel may be used in the tank, if the proportion of vapour present is known to be small, but even in such cases it is better to employ a short suction-tube, the open end of which can be placed at the lowest point in the tank, where most vapour would probably be found. If, on the other hand, the atmosphere of the tank is suspected to contain so much vapour that there would be danger of its producing insensibility when taken into the lungs, and especially if the compartment is entered through a small manhole, it would obviously be most improper that anyone should be sent into the tank, and in that case the sample should be taken by the use of a long suction-tube reaching to the bottom. It is evident that in the case of those tank-steamships which have spaces not filled with oil, but in which oil vapour is liable to accumulate, there would be no great difficulty in having a system of small tubing permanently fitted, which would admit of a sample of the atmosphere being at any time drawn off by means of the collecting cylinder in a part of the ship set apart for the purpose, so that a periodical testing of the atmosphere might thus be effected during the voyage or at any other time.

LUBRICATING OILS.

Specific Gravity.—Mineral lubricating oils of similar character were formerly graded solely with reference to their densities, but as it has been shown that there is no necessary relation between density and lubricating value, it is now generally accepted that the determination of specific gravity is of less importance than that of viscosity. The methods of ascertaining the specific gravity of oils have already been sufficiently referred to.

Colour.—In the case of what are known as "pale oils," exception is taken to any marked increase in the ordinary depth of colour, although as yet there are no generally accepted standards of colour such as have been fixed for kerosene.[1]

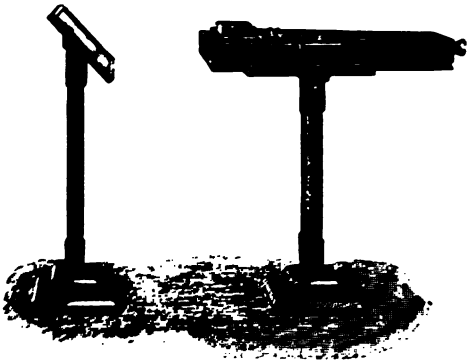

Fig. 225.

Lovibond's Tintometer.—For some years, the Lovibond tintometer[2] has been used in the laboratory of the author for determining the colour of a 2-inch column of lubricating oils, and comparative results have thus been furnished for the guidance of the trade. The instrument consists of a covered trough or box (Fig. 225) divided longitudinally by a partition terminating in a vertical knife edge opposite an eyepiece fixed at one end, two channels being thus formed, which slightly diverge from the end at which the eyepiece is placed. The oil to be examined is contained in a rectangular glass cell placed in one of the channels, and numbered slips of stained glass of known depth of tint are inserted in the other channel until the colour of the oil is matched.

Determination of Flashing Point and Fire Test—Pensky's Instrument for High Temperatures.—Pensky was the first to construct a testing instrument for lubricating oils, which resembles the Abel apparatus. The instrument (Fig. 226) consisted of a metallic oil cup, fitted with a stirrer, C, having a flexible handle, J, and two thermometers, one for the oil, and the second for the vapour space. The oil being poured in up to the gauge, F, the cup was placed in a glass beaker containing water, the temperature of which was gradually raised, or was otherwise heated, a uniform temperature being maintained in the cup by the aid of the stirrer. From time to time, a small gas flame was passed over an opening, L, in the lid until a flash took place. If the oil and vapour thermometers did not indicate the same temperature, the mean was taken.

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[1] In Baku, Stammer's chromometer (see p. 547) is employed in recording the colour of lubricating oils.

[2] *Journ. Soc. Chem. Ind.*, 1890, 10, and Patent Specifications, Nos. 12,867, 1886; 3,859, 1887; and 6,221, 1890.

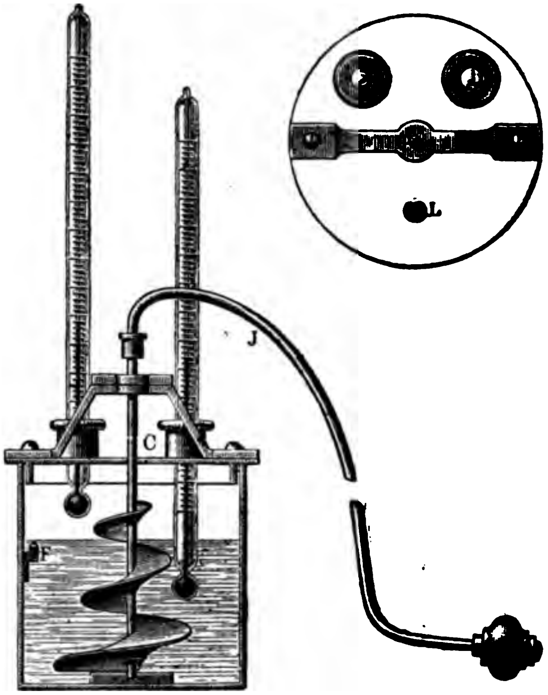

Fig. 226.

The Pensky-Martens Tester.—This instrument is largely employed for determining the flashing point of lubricating oils by the close test. In Fig. 227 the apparatus is shown with the test-flame in position for igniting the vapour; the cover of the oil cup being shown in plan and side view, and a handle, for removing the oil cup, in the separate figures.

Description of the Instrument.—The cover of the oil cup consists of two parts—viz., the portion joined to the rim, and an upper portion which revolves through a small arc. In each portion there are three orifices, the central one being twice the area of the two lateral ones. These orifices may be made to coincide, or the openings may be completely closed, according to the relative positions of the two portions of the cover. The lower part of the cover is fitted with a vertical rod serving as a support to a tube. This tube can be rotated upon the rod by turning the non-conducting milled head at the upper end, and the action compresses a spring. At the lower end, the tube is provided with an arm, which, by the action of the spring, is held against a vertical stud. A pin projecting downwards from the arm, engages with a slot in the revolving portion of the cover, and on turning the milled head, the openings in the upper portion of the cover are brought over those in the lower portion. At the same time, a flange projecting from the edge of the revolving portion of the cover comes into contact with the oscillating test-jet, and this is depressed, so that at the same moment when the central openings coincide, the test-flame is brought to the orifice. On releasing the pressure requisite to turn the milled head, the openings in the cover are again closed by the action of the spring, and the test-jet is brought back to the horizontal position by the weight at the opposite end. This weight is attached to a stem forming a screw valve, by means of which the size of the test-flame can be adjusted. The gas is supplied through a lateral tube forming one of the supports on which the jet oscillates, the other support consisting of a small stud. In the lower part of the cover of the cup, there is a socket for a thermometer, and in the centre of the cover, there is a tube through which the stem of the stirrer passes. This stirrer is provided with a pair of arms working in the oil, and a smaller pair in the vapour space above the oil. It is revolved by means of a flexible wire stem. The oil cup is furnished with a pair of hooks for convenience in removing it from the bath, when hot, by means of the forked holder shown. The heating vessel consists of a cast iron air bath with an annular chamber exposed to the flame, and a brass jacket, which serves to check radiation. The jacket is separated from the iron casting by a considerable space at the sides and by a distance of a quarter of an inch at the top. The oil cup rests upon the jacket, and therefore does not come into contact with the cast iron. Beneath the bath there is a disc of wire gauze which is

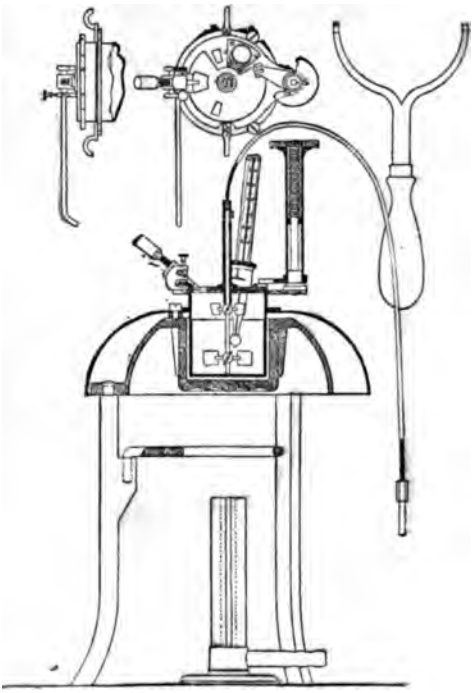

Fig. 227.

fitted to a swinging arm, so that it may be turned aside and the flame of a Bunsen burner allowed to impinge upon the bath, when a high temperature is required.

The author is accustomed to regulate the flame of the burner so that the temperature of the oil rises at the rate of about 10° F. per minute. In employing this, or any other form of close-test instrument in the testing of lubricating oils, it is important that the samples should be free from water, as the presence of aqueous vapour in the upper part of the cup prevents the occurrence of the "flash."

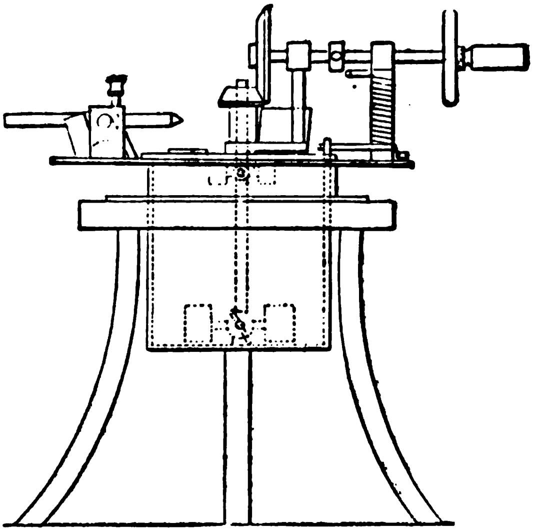

Fig. 228.

If the cover of the oil cup be removed, the apparatus may be employed as an open cup for determining the flashing or igniting point, a gas flame not more than a quarter of an inch in diameter, being used to produce the ignition.

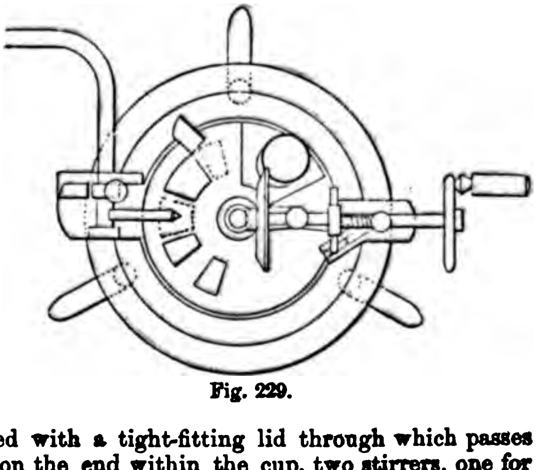

Fig. 229.

Gray's Tester.—Figs. 228 and 229 show Gray's instrument for determining the flashing point of heavy oils.[1] The apparatus consists of a brass oil cup of the same dimensions as that employed in the Abel instrument, supported on a tripod stand and covered with a tight-fitting lid through which passes a steel shaft carrying on the end within the cup, two stirrers, one for the oil and the other for the vapour. The upper end of the shaft terminates in a bevelled wheel engaging with another similar wheel on a horizontal shaft supported by two bearings and rotated by a handle fixed in an ebonite disc on its further extremity. This shaft also carries a collar from which project two pins at diametrically opposite points. These, when the shaft is drawn out a little way so as to disengage the bevel wheels, come into position for applying the test-flame. In the lid are three openings—one immediately in front of the test-flame, and the others on either side of it. The sliding cover is pierced with two orifices corresponding to those on the lid, and is kept closed (as shown in Fig. 229) by a spring while the bevel wheels are in gear. On drawing back the shaft, one of the projecting pins engages with the horizontal arm of an upright rod connected with the slide, which is turned round when the handle of the shaft is moved about a quarter of a revolution, the openings in the lid being thus uncovered and the test-flame simultaneously applied. Where gas is not available for the test-flame, a good substitute is obtained by passing a current of air or hydrogen through cotton wool or other absorbent material saturated with gasoline.

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[1] *Journ. Soc. Chem. Ind.*, 1891, 348.

Directions for Use.—The following are the directions prescribed by the inventor:—The oil cup being filled up to the mark inside with the oil to be tested, the thermometer is placed in its socket and heat is applied either by a direct flame or by the interposition of a sand bath. The test-flame is adjusted to a diameter of about one-eighth of an inch. During the heating, the stirrers should be rotated at short intervals, and in proportion to the rate at which heating progresses. When the expected flashing point is approached, the heating should be more gradual, to ensure greater accuracy in the test; and a rough test to ascertain this point may be first made. Observations may be taken every degree or half-degree, giving the stirrer a few turns before each. The rate of heating is immaterial, provided it is not too rapid to allow of readings being taken.

The Treumann Tester. — The Treumann tester (Fig. 230), employed for determining the flashing point of mineral lubricating oils on the German State railways, is thus described by Künkler.[1] The oil cup is a cylindrical porcelain crucible 4 centimetres high, and of the same internal diameter. It is filled with the oil to a distance of 1 centimetre from the top, and is placed on, but not enveloped by, a layer of sand 1½ centimetre deep, in a hemispherical iron or tin capsule 18 centimetres in diameter, supported on a tripod. The bulb of a thermometer divided between 100° and 200° C., and supported by a clamp, is completely immersed in the oil.

Directions for Use.—The bath is slowly heated, especial care being exercised when the temperature exceeds 100° C. to avoid local heating; and when the temperature at which the first test is to be made has been reached, the test-flame, which is 10 centimetres long and is supplied with gas through an indiarubber tube, is passed horizontally backwards and forwards over the oil, so that it is exposed to the vapour for a period of four seconds each time. Care must be taken that the flame does not touch the oil or the edge of the oil cup. The test is applied first at 120° C., and afterwards at intervals of 5° until 145° C. is reached. Beyond this point, it is repeated at intervals of 1° until a momentary flash occurs.

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[1] *Die Maschinenschmierungs*, 1894.

In Fig. 230, A is the oil cup; B, the sand bath; C, the thermometer, supported by the clamp, S, on the rod, D; E, the tripod stand; F, the Bunsen burner; and G, the test-jet. In making the test, it is recommended that the jet, G, should be rested upon the edge of the sand bath, and the flame moved slowly and regularly once forwards and backwards horizontally over the surface of the oil during four seconds, without coming into contact with the oil or the walls of the cup. This system of testing is referred to in greater detail in the *Mittheilungen aus den königlichen technischen Versuchsanstalten zu Berlin, herausgegeben im Auftrage der königlichen Aufsichts-Kommission*, 1893, part ii., 37, and certain defects are pointed out, preference being given to the Pensky tester.

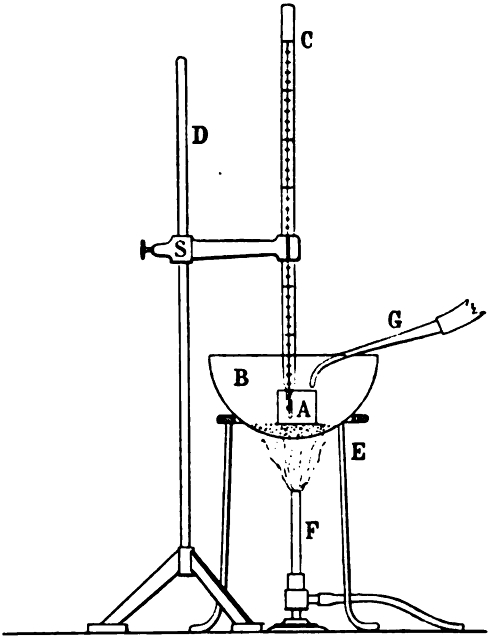

Fig. 230.

United States Fire-test.—In the United States, it is customary to use, in ascertaining the fire-test, a shallow open metallic cup, supported on a tripod stand and heated directly by the flame of a spirit lamp, the temperature being raised at the rate of 8° F. per minute.

Volatility Test.—In some cases, the volatility of the oil is tested by noting the loss of weight sustained by a given quantity of the oil when exposed for a specified length of time in a shallow vessel, to an elevated temperature, the oil being sometimes absorbed by filter-paper before exposure to heat. The author is accustomed to expose 25 grammes for twelve hours in a shallow dish, to a temperature of 150° F. in the case of engine and spindle oils, and 250° F. in the case of cylinder oils. It is, however, difficult to prescribe any conditions under which concordant results can be always obtained, and the test is not a satisfactory one, according to the author's experience.

Lubricating Value.—The lubricating value of an oil is now usually deduced from its viscosity, though in some cases, frictional tests are made with machines which will be described later.

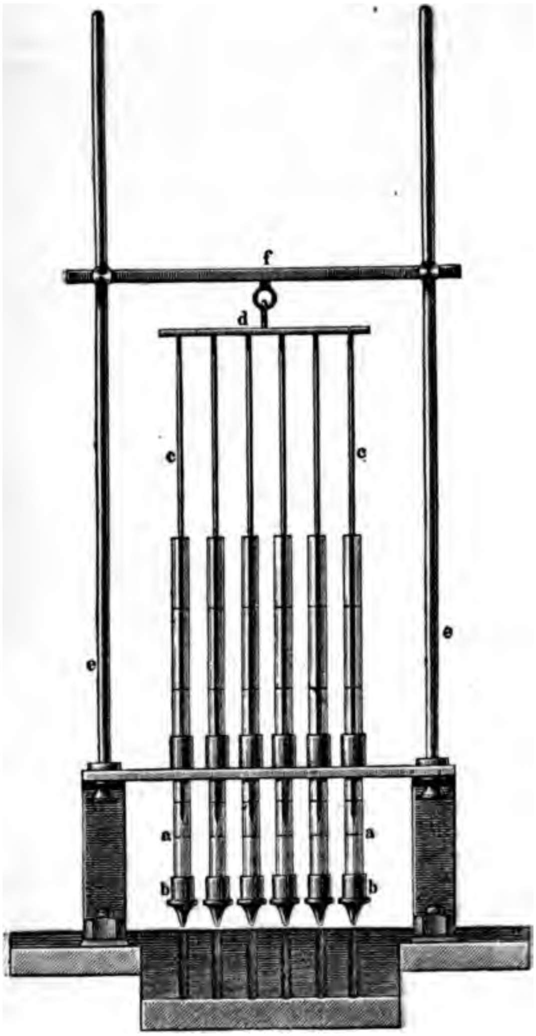

Fig. 231.

Determination of Viscosity.—Although the results afforded by the use of a viscometer are purely arbitrary, and the viscosity as determined with one form of viscometer is not usually strictly comparable with that ascertained by means of another of different construction, yet each of the viscometers generally employed admits of being accurately standardised, so that any number of instruments of a given form may be constructed to give practically identical results. Viscosity is now regarded as one of the most important characters of a mineral lubricating oil, and several forms of apparatus for determining it are in use.

The Redwood viscometer has been adopted by the War Department, the principal Railway Companies, the Scottish Mineral Oil Association, and the petroleum trade generally, while the Engler viscometer occupies a similar position in Germany, and the Saybolt viscometer is largely used in the United States.

Nasmyth's Apparatus.—It is well known that practical men have long been in the habit of making a rough comparison between samples of lubricating oils by noting the length of time occupied in the flow of a given quantity over the surface of an inclined plate of glass. Probably the first instrument constructed for carrying out this test with some approach to precision was that of Nasmyth.[1] The apparatus consisted of a plate of iron 4 inches wide and 6 feet long, provided with six similar longitudinal grooves or channels. The plate was fixed so that one end was an inch higher than the other, and the oils to be compared were simultaneously poured in equal quantities out of a row of small brass tubes into the upper ends of the grooves, the rate of flow along the channels being carefully noted.

Albrecht's Apparatus.—Dr. M. Albrecht[2] improved Nasmyth's apparatus, by suspending in a frame (see Fig. 231), above the upper end of the channels, calibrated glass tubes, *a*, terminating in fine nozzles, *b*, of brass exactly over the centre of each groove. The apertures of the nozzles are closed by fine brass wires on the ends of rods, *c*, connected by a crossbar, *d*, hanging from a bar, *f*, which is adjustable on supports, *e*, so as to admit of being lifted simultaneously at the commencement of the test, and replaced when a determined quantity has run from each tube.

Phillips' Fluidimeter.—An instrument recently devised by Mr. H. Joshua Phillips for determining the fluidity or viscosity of oils at various temperatures, is thus described by the inventor:—"The instrument consists of a copper bath 14 inches long, 9 inches wide, and 1½ inch deep, provided with a stout gun-metal plate containing six cups and graduated grooves. It is swung upon elevated bearings from two studs projecting from the centres of the longitudinal sides, and can be fixed by means of thumbscrews. A protractor is fixed to the side, with an index upon the support, and the bath can be tilted at any desired angle to or from the operator. At the top of the bath, are two holes, one for the thermometer, and the other for pouring in water or oil to be maintained at a definite temperature by a Bunsen burner. The grooves are 10 inches long, and graduated into ⅛ degrees. The surface is nickel plated, and a stout glass plate is provided as a protection against air currents."

Directions for Use.—"Water or oil having been run into the bath at any desired temperature, a small Bunsen burner is placed under the bath, regulated so as to maintain it at the same temperature. The oils to be tested are poured into test-tubes provided with pipettes, and heated in a bath of water or oil until the desired temperature is attained. The bath is now tilted at an angle of 2½° from the horizontal, from the operator, and the oils run into the cups until they reach the zero mark on the scale about an inch from the cups. The glass plate, previously warmed to about the same temperature as the oils, is now slid on, the bath tilted at any desired angle to the operator, and the time noted that the oils take to reach the 10-inch mark. The time of flow of the oils is found to be practically inversely proportional to the angle of inclination, provided the angle is sufficiently great, or the temperature sufficiently high, to allow the oils to run quick enough to minimise errors due to oxidation or cooling of the oil by air currents. This seeming deviation from the laws of gravitation is, of course, due to the decrease of acceleration consequent upon the loss of "head" and gradual loss in weight of the oil as it flows to the terminus. For instance, the following results were obtained with pure rape oil at a temperature of 180° F.:—

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[1] *Mechanic's Magazine*, 1850, liii., 313.

[2] *Die Schmiermittel. Albrecht*, 1879, 18.

Angle.	Distance.	Time in Secs.
2½°	10 inches	33
5°	10 ,,	16
10°	10 ,,	8

"A sample of mineral engine oil gave:—

Angle.	Distance.	100° F.	140° F.	180° F.
2½°	10 inches	160	60	28
5°	10 ,,	79	30	14

"From these results, it would appear that the time of flow could be calculated for any desired angle from one determination at a definite angle. The following results were obtained in comparing the viscosity of pure rape oil at different temperatures with Redwood's viscometer, assuming the rate of flow to be 1 at 180° F.:—

At	Phillips' Fluidimeter.	Redwood's Viscometer.
180° F.	1·00	1·00
140° F.	1·59	1·56
100° F.	3·19	3·14
60° F.	7·50	7·37

"The great advantage the writer (Mr. Phillips) has found in using the instrument is that in cases where several oils have to be examined and to be compared with a standard, a great saving of time is effected, inasmuch as all oils that do not approach the standard in fluidity can be discarded, and an exhaustive examination made only of the oils that agree in fluidity with the standard."

Pipette Viscometers.—The simplest instrument for determining the viscosity of an oil consists of a glass pipette which is filled to a mark in the neck and allowed to discharge its contents. The relation between the time of outflow of the sample and that of a standard oil, indicates the viscosity of the sample in terms of the standard. It is, however, difficult to standardise such pipettes, since the form of the constriction, apart from the size of the opening, affects the result, and different pipettes standardised with an oil of a certain viscosity, do not necessarily give concordant results with an oil of very different viscosity. The maintenance of the required temperature of a sample in a glass pipette is also not easily effected. For these reasons, the **jacketed glass viscometers of Veitch-Wilson, M'Ivor, and Sacker** have not been found to give sufficiently accurate results.

Napier's Viscometer.—The advisability of reducing the observed viscosity to a standard density, appears to have been first suggested by Mr. Napier, of Glasgow. In his instrument, the oil cylinder consisted of two parts connected by a flexible tube. The upper part was so supported that it could be placed at a given height on a fixed scale, according to the specific gravity of the oil, and was provided with an overflow pipe, so that, by using a reservoir with a stopcock, a slight continuous overflow could be produced, and the oil level thus kept constant.

Mason's Viscometer.—In the *Chemical News* for October 31, 1884, Professor W. P. Mason, of Troy, N.Y., gave the following particulars of a viscometer in which the column of the oil could be so adjusted in height as to be inversely proportional to the specific gravity, and could be maintained at that height during the experiment:—

A glass cylinder 22 inches (55·9 cm.) long, 1¼ inch (3·18 cm.) diameter, has a brass plate on the lower end an eighth of an inch (0·318 cm.) thick. An orifice is bored in the centre of the plate $\frac{1}{32}$ inch (0·0794 cm.) in diameter, with bevelled edges, chamfered back half an inch (1·27 cm.), thus producing a sharp-edged orifice. A line marking the 18-inch (45·72 cm.) level is cut on the glass, with several finer lines above and below, an eighth of an inch (0·318 cm.) apart, ranging from 16 to 21 inches (40·64 to 53·34 cm.) above the orifice. The standard temperature is usually 60° F. (15·5° C.). A total flow of 6·103 cubic inches (100 c.c.) is recorded, after adjusting the supply so that the head shall be as nearly as possible equal to 18 inches (45·72 cm.) of water, determining this head by calculation from the specific gravity of the oil. The rule for obtaining the viscosity is to note the time required to discharge the 100 c.c. (6·103 cubic inches), and divide this time by that required where water under a head of 18 inches (45·72 cm.) is used. This ratio is the measure of the viscosity.

Redwood's Viscometer.—The Redwood viscometer (Figs. 232 and 233) is a modification, designed by the author in 1885, of the instrument formerly used at the Battersea Works of Price's Patent Candle Company. It consists of a silvered copper oil cylinder, about 1⅞ inch in diameter and 3½ inches in depth, furnished with an agate jet fitted into a slightly conical metal seating. The cylinder is fixed in a brazed copper water bath provided with a copper heating tube projecting at an angle of 45° from the side near the bottom, as well as with a revolving agitator carrying a curved shield to prevent splashing, and a thermometer to indicate the temperature of the liquid in the bath. The oil cylinder has a stopper consisting of a small brass sphere which rests in a hemispherical cavity in the agate jet. The sphere is attached to a wire by means of which it is raised and suspended from a standard which supports a thermometer in the oil. Inside the oil cylinder, and at a short distance from the top, is fixed a small bracket terminating in an upturned point, which serves as a gauge of the height to which the cylinder is filled. The instrument is supported on a tripod stand, furnished with levelling screws. Great care is taken in the construction of the agate jets to secure uniformity, and any small differences in the rate of flow, are corrected by slightly altering the position of the pointed bracket in the oil cylinder. The instruments are thus all standardised. The viscometer is used in the following manner:—The bath is filled with a suitable liquid to a height corresponding with the point of the bracket in the oil cylinder. Water may be used for temperatures up to 200° F., and a heavy mineral oil for higher temperatures. The liquid being at the

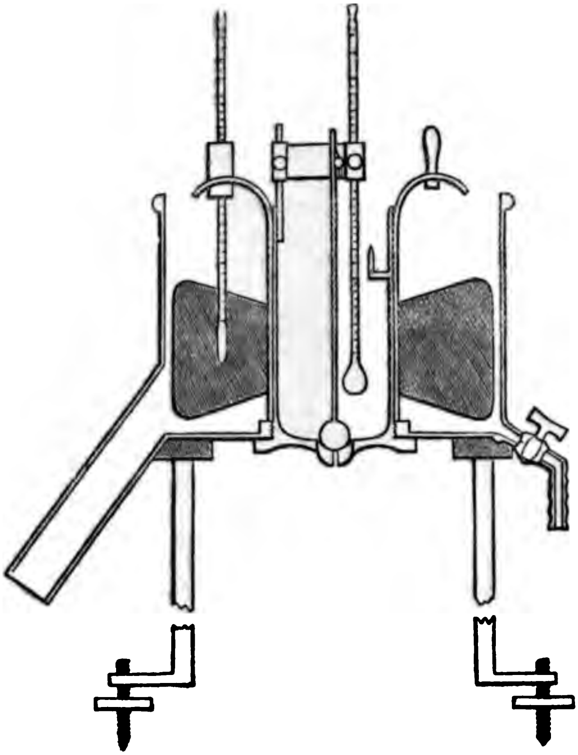

Fig. 232.

required temperature, the oil to be tested, which may previously be brought to the same temperature, is poured into the inner cylinder until its level just reaches the point of the gauge. A narrow-necked flask, holding 50 c.c. to a point marked on the neck, is placed beneath the jet, in a vessel containing a liquid of the same temperature as the oil. The ball valve is then raised, a stop watch at the same time started, and the number of seconds occupied by the outflow of 50 c.c. noted. When oils are being tested at a temperature much above that of the laboratory, a gas flame is applied to the heating tube, and the agitator kept in gentle motion throughout the experiment. The maintenance of the exact required temperature of the oil is thus, after a little practice, rendered easy. It is important that the apparatus should stand perfectly level, and that the oil should be free from dirt, water, or other suspended matters. In order to express the results in terms of the viscosity of rape oil at 60° F., the standard used with this instrument, the number of seconds occupied by the outflow of 50 c.c. of the oil is multiplied by 100 and divided by 535, the average number of seconds occupied by the outflow of 50 c.c. of rape oil at 60° F. from the apparatus. The result is multiplied by the specific gravity of the oil at the temperature of testing, and divided by 0·915, the specific gravity of refined rape oil at 60° F., a correction being thus made for the difference in the specific gravities of the two oils. The time occupied in the outflow of 50 c.c. of water, at 60° F., is 25·5 seconds.

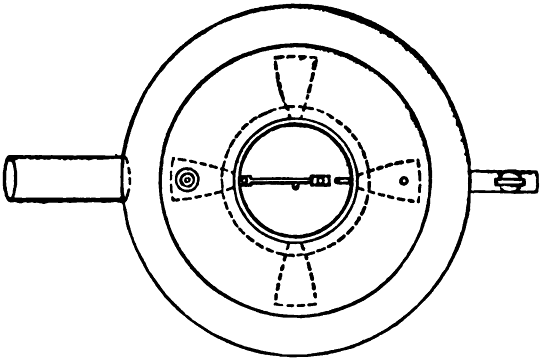

Fig. 233.

The author attaches considerable importance to the employment of agate in the construction of the jet, as this material is not liable to become worn or injured, even if the instrument is subjected to somewhat rough usage. He has had one of these viscometers in almost daily use in his laboratory at temperatures ranging from 70° to 250° F. for the past ten years and the jet shows no sign of wear. He also regards the provision of an effective stirrer for the bath as highly desirable, for it is essential that the temperature of the oil subjected to the test should be most accurately adjusted and maintained. In the original standardising of the instrument, *slight* departures from the standard size of the orifice may be corrected by placing the gauge point a little higher or lower. If, however, there be any considerable deviation from the model, especially in respect to the height of the column of oil, the instrument may be standardised to give the same results as the pattern with a certain oil, but will not necessarily furnish concordant results with another oil of different viscosity.

Engler's Viscometer.—The following description of the Engler viscometer is derived from the *Zeits. f. angew. Chemie* of 1892, and from *Dingler's polytechnisches Journal*, 1892, cclxxxvi. :—

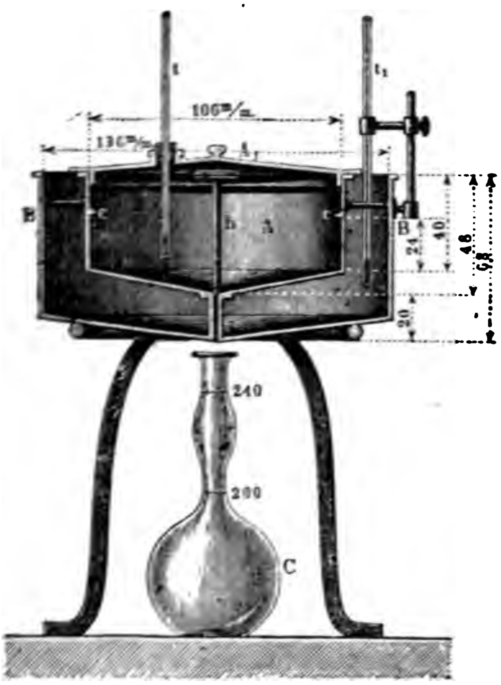

Fig. 234.

In 1884, at the request of the *Tarif-Kommission der deutschen Eisenbahnen* (Committee of the German State Railways), Dr. C. Engler experimented with a view to the construction of a viscosity instrument for mineral lubricating oils, and his apparatus was adopted by the *Kommission* in their report of 31st May, 1884, as the official test on the railways. An account of it was given in the inventor's paper in the *Chemiker Zeitung*, No. 11 of 1885, 1st Feb.

Complaints having arisen with regard to the irregular results yielded by the instruments of different makers, which although professedly standardised, exhibited fundamental departures from the original model, Dr. Engler, in 1892, brought out the improved form shown in the figure, and stated that the only instruments which would in future be recognised as normal were those made by C. Desaga, of Heidelberg, and bearing the standardising mark of the Grand Ducal Techno-chemical Testing and Experimental Institution in Carlsruhe. The apparatus (Fig. 234) is provided with an oil cup, A, of brass, closed by a lid, A_1. The oil cup is of the dimensions given in the figure, and its inner surface is gilt. In the centre of the convex bottom of the oil cup, is an outflow tube, *a*, of platinum (brass being attacked by the oil after being some time in use) 20 mm. long and 2·9 mm. internal diameter at the top, decreasing to 2·8 mm. at the outlet. This tube can be closed by a pointed rod, *b*, of hard wood, introduced through the lid of the cup. Three small pointed studs, *c*, turned up at right angles,[1] on the walls of the cup, serve to indicate the surface level of the oil, marking a capacity of 240 c.c., and also show whether the apparatus is properly adjusted as regards level. A thermometer, *t*, is inserted in the lid to register the temperature of the oil. The oil cup is fixed in an open oil bath, B, containing a thermometer, t_1. The oil bath is supported by a tripod stand, and is heated by means of a ring burner. A measuring glass, O, marked at 200 c.c. and at 240 c.c. is placed exactly below the pipe, *a*.

To ensure the attainment of satisfactory results, the dimensions given must be strictly adhered to, for, although the error caused by altering some of them can be corrected, so far as the flow of water at 20° C. is concerned, by varying the length of the pipe, *a*, the correction is of no value for *oils* at other temperatures, and the difference in result between such instruments and one of standard dimensions increases with the viscosity of the oil tested.

Every instrument, even when standardised, should be tested before using the first time, and again after having been some time in use, by carefully rinsing out the cup with ether, alcohol, and water, in succession, carefully drying the outflow pipe with a strip of filter paper, and observing the time required for the outflow of 200 c.c. of water maintained at 20° C. The water should be quite free from any rotary motion before the vent peg is withdrawn. The time should be 51 to 53 seconds, and the test should be twice repeated. The difference should not exceed 0·5 second, and the decimals of the average are counted as one second. To test oils, the cup must be most carefully cleansed of all damp and dirt, rinsed with alcohol, ether, and petroleum in succession, and then filled with the oil up to the gauge points. The oil having been brought to the desired temperature by heating the oil bath, and maintained at that point for two or three minutes, the peg is withdrawn, and the outflow timed by a good chronometer. The result in seconds, divided by the rate for water at 20° C., gives the viscosity of the oil, *e.g.*—

Rate of flow of oil, 276 seconds.
,, ,, water at 20° C., 53 seconds. Result = 5·2.

Oil containing suspended particles, solid matter, or water, must be filtered or dried before testing.

Saybolt's Viscometer.—In the Saybolt viscometer (Fig. 235) the oil vessel is placed in a water bath of considerable capacity. The jet of the viscometer is of metal and is enclosed in a tube extending below the orifice. The oil vessel is contracted, as shown, above the jet, and is cut away longitudinally on each side, to expose a glass tube which lines it. Glass windows are provided in the water bath.

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[1] These studs should have been represented in the figure as pointing vertically upwards.

The upper edge of the oil vessel is fitted with an oil-tight gallery having a raised edge, and communicating with the oil vessel, which extends to the same level as the top of the gallery, by a number of small holes. In using the apparatus, the water bath is filled with water at the required temperature, and a cork having been inserted in the mouth of the tube enclosing the jet, the oil vessel is filled with the sample to be tested until overflow occurs through the holes into the gallery. The oil is then stirred with a thermometer and the temperature adjusted if necessary. On withdrawing the thermometer, the oil which it had displaced flows back from the gallery, which is then emptied by means of a pipette. The length of the oil column is of course determined by the position of the holes connecting the oil vessel with the gallery. The flow of oil from the jet is started by withdrawing the cork, and a stop-watch is set in motion. The watch is stopped when the operator sees the surface of the oil through the glass tube above mentioned.

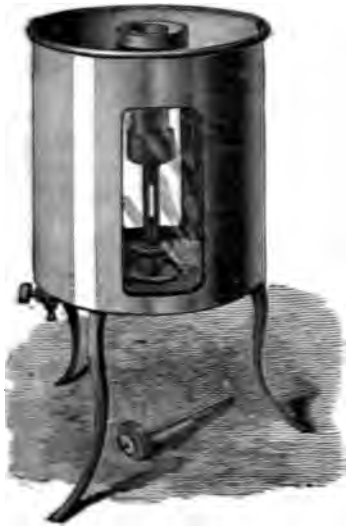
Fig. 235.

Comparison of Results.—The relation between the results afforded by the instruments last described, is not precisely the same with all oils, but is approximately as shown in the following table, which is based upon a number of experiments made in the author's laboratory:—

Redwood Viscometer. Seconds for outflow of 50 c.c. at 70° F.	Engler Viscometer. Seconds for outflow of 200 c.c. at 20° C.
100	170
Redwood Viscometer. Seconds for outflow of 50 c.c. at 70° F.	Saybolt Viscometer. Seconds for outflow at 70° F.
100	56

Engler and Künkler's Modification.—In order to overcome the objection to the Engler viscometer when used at high temperatures, that the end of the outflow tube is liable to cool below the temperature recorded, Engler and Kunkler devised the following apparatus[1]:—The outer casing (see Figs. 237 and 238) is of octagonal section, and is 35 centimetres high and 20 wide. It is made of stout brass plate, and is double walled. It stands on four triangular feet, *a*, the slanting sides of which rest on the inner edge of the ring of a tripod stand, so that the instrument is easily levelled. On the bottom, is screwed a concave copper heating plate, *b*, for distributing the heat from a Bunsen flame. A tripod, *c*, resting on this plate supports a graduated receiving flask, *e*, protected by asbestos cloth, *f*, and above this is placed a horizontal plate, *g*, having a central aperture, *h*, for the descending oil, and four

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[1] *Dingler's polytech. Journ.*, 1890, cclxxvi., 42.

ng up to the level of the oil cup and
oute the heat. The oil cup, *k*, rests on
ate, and is fitted with a thermometer, *s*;
stirrer, *p*, moved by a handle, *o*, above
a revolution, so as not to interfere with

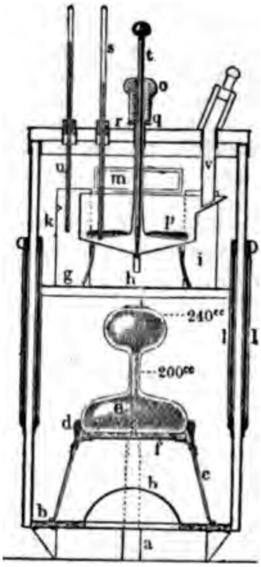

Fig. 238.

d rod, *t*, for closing the outflow tube—
ometer, *u*, for the air chamber, project
ıratus.

The stirrer can be lifted out of the oil and supported by a projecting pin when not in use. There are two windows, *m*, on opposite sides, level with the top of the oil cup, and two double windows, *l*, on opposite sides of the lower chamber. The oil, before being placed in the viscometer, is warmed to the required degree in a double-walled can (Fig. 236), fitted with a thermometer and a stirrer, *x*. The blades of the stirrer are fixed at different heights on the spindle, so as to promote circulation of the oil from below upwards. The bottom of the can is covered with asbestos cloth. It was found by the inventors that up to 100° C. the distribution of heat over the interior of the apparatus was regular, with the exception of the stagnant layer of air at the bottom of the viscometer, which was a few degrees lower. The latter condition was also observed at temperatures above 100° C. in increasing degree, amounting to 4° at 150° C., but the difference was not found to affect the result of the test.

The receiving glass being placed on its stand and the horizontal plate and viscometer inserted in the case, the lid is fixed in position, care being taken that the marks on the lid, viscometer, and plate, correspond with the mark on the edge of the case. The air chamber thermometer is inserted so that its bulb almost touches the viscometer, and the bulb of the oil thermometer is also lowered as far as possible without touching the bottom of the cup. The filling tube, stirrer, and vent stopper are all placed in position, and after levelling the apparatus by the plumb line at the side, heat is rapidly applied until four-fifths of the desired temperature is reached, when the flame is continuously decreased till the right degree is attained and remains constant, as indicated by the air chamber thermometer.

Meanwhile, the heating can has been filled with oil nearly up to the mark, and carefully heated to the proper temperature, the stirrer being meanwhile moved in the direction of an arrow on the lid, and is then filled quite up to the mark. When both oil and apparatus are at the right temperature, the former is quickly poured into the viscometer, and the filling tube is closed. After ascertaining that the oil reaches exactly up to the mark, the stirrer is moved (holding the vent peg in position during this operation), and when the temperature is registered as correct, the stirrer is drawn up and suspended by its side pin, and the vent peg is withdrawn, the hole in the stirrer knob being closed by a peg provided for that purpose. The time required for the passage of 200 c.c. of the oil from the cup into the receiving glass, is the measure of the viscosity. It is well to allow the oil to exceed the required temperature by $\frac{1}{4}$° or $\frac{1}{2}$° before pouring it into the viscometer. If a little too hot, it may be cooled by slightly reducing the temperature of the air chamber. It is important that the oil should not be heated or cooled too rapidly, as either affects its temperature during the transfer to the apparatus, and the stirrer should be well worked before reading the temperature or pouring out the oil.

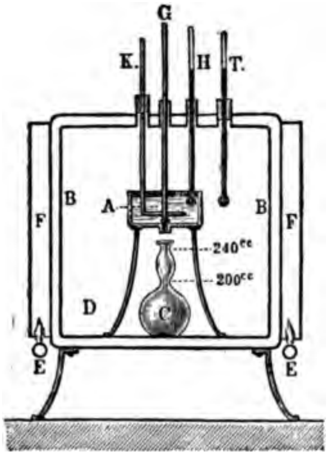

Fig. 239.

Engler-Künkler-Martens' Viscometer.—The Engler-Künkler viscometer has been further modified by Martens, as shown in Fig. 239.[1]

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[1] See *Zeits. f. anal. Chemie.*, 1893, 583.

The oil cup, A, stands on a tripod in a double-walled chamber, B, having a glass door, D, at the back, and a glass disc in the front. The air bath is heated by a curved burner, E, placed beneath wings, F, on the chamber, B. Thermometers, H, T, indicate the temperature of the oil and air. The oil is stirred by a platinum wire, K. The temperature may be regulated by temporarily opening the door, D. The oil is allowed to flow out by raising a stopper attached to a rod, G. This apparatus is readily cleansed, and being wholly contained in the air bath, there is no risk of the oil being cooled as it flows from the vessel, A.

Künkler's Modification.—A. Künkler[1] has devised a modification of the Engler viscometer for use at low temperatures. The oil cup, 6 centimetres in diameter, and containing, up to a mark, 75 c.c., rests on four feet in a refrigerating bath. The outflow tube is 20 mm. long and 7 mm. wide, and can be closed by a pointed rod projecting through the lid. The draining pipe of the cooling bath is fitted with a pinch-cock. The whole rests on a truncated metal cone, which contains a graduated receiving glass of 50 c.c. capacity, and serves to protect the outflow tube from external heat. Two side windows admit of the inspection of the course of the test. The apparatus is levelled by set screws. The instrument is standardised by observing the rate of outflow of glycerine, of 1·200 specific gravity (= 24° Baumé) at 17·0° C., previously cooled to 0° C., and allowed to stand five minutes in the oil cup before testing, the outside bath being filled with ice water. The test is applied as follows:—

Oil at 17° C. is poured in up to the mark, the lid is closed, and a refrigerating mixture giving a lower temperature than that required for the experiment, is placed in the bath. The oil is then stirred with the thermometer until the requisite temperature is reached, whereupon the cup is closed, and water is poured into the bath until that is also of the same temperature. The temperature is carefully maintained throughout the test, by the application of water or cooling mixture, keeping the liquid up to within 1 to 1·5 cm. of the lip of the bath. An hour is allowed to expire before the oil is run out. The time required for 50 c.c. of the oil to run through, is compared with the glycerine standard.

Künkler's Viscometer for Greases.—Künkler[2] has devised the following instrument (Fig. 240) for comparing the relative consistency of machine greases by their rate of flow under a given temperature (usually 50° C.) and pressure. It is made of brass, and has a water bath, *a*, which can be maintained at a constant temperature by heating a side chamber, *g*. In the centre is fixed a cylindrical vessel, *b*, terminating in a small tube, *d*, 6 mm. in diameter, and 15 mm. long, projecting through the bottom of the bath. The bath is provided with a thermometer, *f*. A tube, *c*, 30 mm. in diameter and 150 mm. in length, fitting into the cylinder, *b*, contains the grease to be tested. A piston, *e*, 75 mm. in length, and consisting of two circular plates 29 mm. in diameter connected by a rod, slides in the tube, *c*, and presses the grease through the tube, *d*. The piston is continued above the upper plate as a tube, *o*, which, by means of a guide strip fitting in a groove, *n*, is kept perpendicular. On the upper end of the tube, *c*, fits a cap, *h*, with two opposite inward projections, *i*, its movement being restricted by a projecting stud fitting in a slot, *m*. The tube, *o*, is provided with four

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[1] *Zeits. f. anal. Chemie.*, 1893, xxxi., 586.

[2] *Chem. und Tech. Zeitung*, xi., No. 21, 670-672; see also Künkler's *Maschinenschmierung, die Schmiermittel und ihre Untersuchung*, published in Mannheim, 1894.

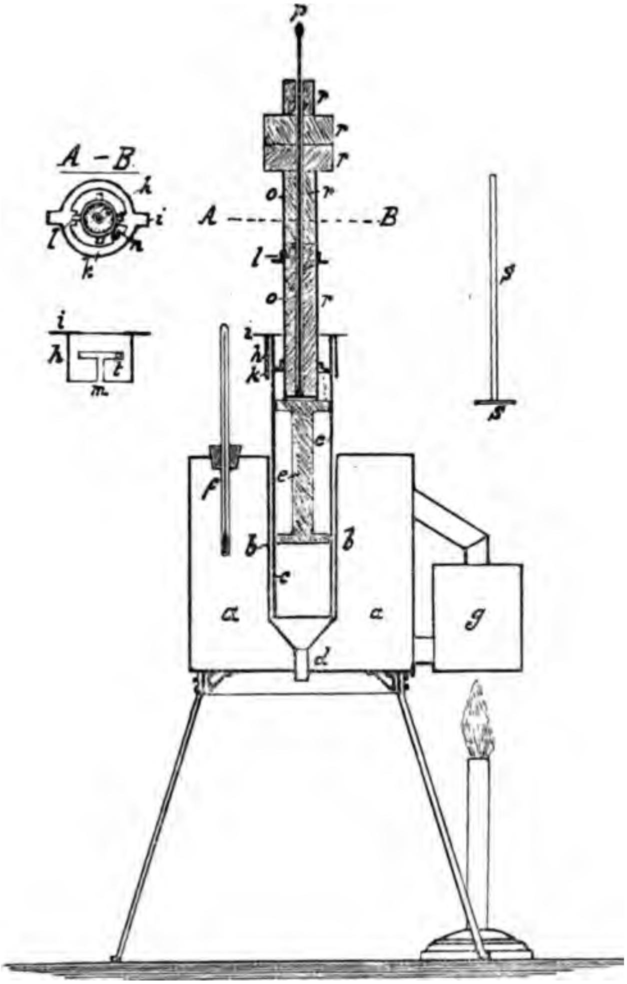

Fig. 240.

projecting studs, two upper, *l*, and two lower, *k*, which rest on the projections, *i*. The tube is thus supported by the lower studs until the test is commenced, when on being slightly turned, it is free to descend until its movement is arrested by the upper studs. The two pairs of studs are 55 mm. apart. In the tube, *o*, an upright rod, *p*, terminating below in a plate, serves to hold in place the weights, *r*, *r*, *r*, *r*, *r* (3 of 200 grammes, 1 of 100 grammes, and 1 of 50 grammes). The weight of the piston and the rod, *p*, is 170 grammes. As the consistency of greases is greatly affected by differences of temperature and by stirring, it is essential that the grease tube, *c* (of which three are provided with each apparatus), should be filled twenty-four hours before using, and be kept at 20° C. The filling is accomplished by applying the grease with a knife or spatula to the lower plate of the piston, and gradually drawing the latter up the tube, taking care that no air space is formed. The operation is completed by the aid of a ramrod, S, and the tube is full when the upper plate of the piston reaches the top of the tube. 50° C. is the usual temperature for the test. To ensure this, the bath is filled to 1·5 cm. from the top, with water at 55° C., this temperature being maintained by the aid of the heating lamp. The grease tube, *c*, being placed in the cylinder, *b*, the piston is inserted, and the cap, *h*, placed in position to intercept the studs, *k*. After standing for twenty minutes, during which time the weights are put in place, the cap, *h*, is turned round, and the piston allowed to descend until the upper studs rest on the edges of the cap, *h*, when the test is at an end, the time occupied being the measure of the consistency of the grease. According to the nature of the grease to be tested, the weights are varied so that the operation shall occupy about ten minutes: this is ascertained by an approximate preliminary test. The test is only a comparative one, there being no relation between the results obtained by using different weights. After each test, the piston should be cleaned and cooled, and the conical bottom of the cylinder, *b*, cleared of adherent grease.

Künkler's Viscometer for Small Samples.—In order to admit of the viscosity of a lubricating oil being determined with smaller samples than are necessary when the ordinary viscometer is used, Künkler[1] has devised a form of apparatus suitable for quantities as small as 30 c.c. The apparatus (Fig. 241) is provided with an external oil or water bath, *w*, of sheet brass, with a copper bottom, cylindrical in form, and turned outwards at the top. Heat is applied to the bath by means of a spirit lamp or gas flame, and the temperature of the contained liquid is indicated by a thermometer suspended by a bracket clip, *x*. In the bath is a movable stand, *d*, on four legs which extend to the circumference. The stand also has a pair of arms, *h*, which hook on to the bevelled edge of the bath. The viscometer proper rests on this stand, and is fastened to it by a spring clip, *i*. It is in the form of a double globular flask of strong glass, the two parts being connected by a capillary tube, *c*, 30 mm. in length. The upper globe, *e*, is 40 mm. in diameter and carries a filling tube, *k*, 13 mm. wide and 65 mm. long. From the side of the lower globe, *a*, rises a tube, *b*, through which 25 c.c. of oil are drawn, by exhaust, from the globe, *e*, up to a mark, *g*. The globe, *e*, is furnished with a thermometer inserted through a loosely fitting cork in the filling tube, *k*, and is etched with a filling mark at a height of 35 mm. above the mouth of the capillary tube. The width of this latter tubing is such that distilled water at 20° C. would rise in it to a height of 50 mm. The height of the ascending tube, *b*, is 125 mm., and its internal diameter 5 mm. This tube extends horizontally for a length of 75 mm. and is provided with a tap, *m*. A stay, *l*, fastens the tube, *b*, near the top, to the rest of the apparatus. The exhaustion apparatus consists of two globes united by a tube, *s*, the upper one, *r*, being 48 mm. in diameter and etched with a filling mark, *p*, while the lower, *t*, is 56 mm. in diameter, and has a filling tube, *v*, at the highest point. The vertical distance from the mark, *p*, to the centre of the lower opening of the tube, *s*, is 160 mm. The exhauster is connected with the viscometer by a strong indiarubber tube, 120 mm. long, joining the horizontal end of the tube, *b*, to another tube of the same length and inside diameter, and likewise fitted with a tap, *o*, extending from the globe, *r*. The apparatus is standardised by using an aqueous solution of glycerine of 1·110 specific gravity at 20° C., mercury being employed as the exhaust fluid. The rate of flow, per second, of the glycerine solution (the mean of three tests being taken) is the standard of comparison for oils, their viscosity being determined at the average temperatures to which they are exposed in practice, viz., 50° C. for machine oil and 150° for cylinder oil, with the employ-

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[1] *Dingler's polytech. Journ.*, 1893, ccxc., 281.

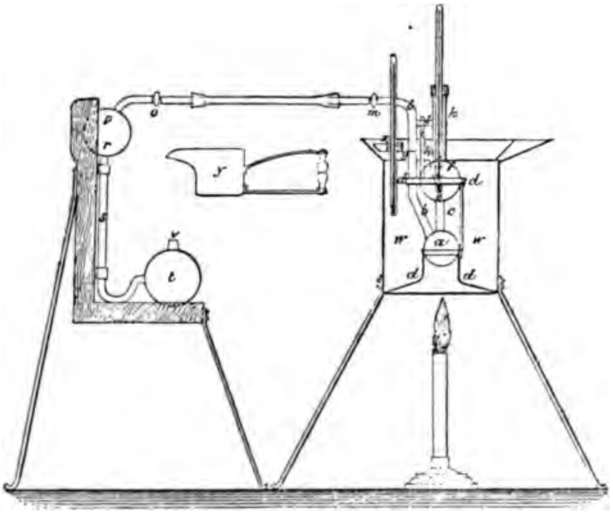

Fig. 241.

ment of mercury as the exhaust liquid for temperatures below 100°, and water for higher ranges.

In conducting the test, the exhauster is filled from the lower globe, with the liquid employed, until the level of the mark, *p*, is reached, taking the *upper* meniscus in the case of mercury and the *lower* in the case of water. Care must be taken to leave but little of the liquid in the lower bulb, so as to avoid stopping the mouth of the tube, *s*, before it is emptied. The indiarubber tube is put into position, the viscometer placed in its stand, *d*, and the spring clip, *i*, slipped over the stay, *l*, both the taps, *o* and *m*, being kept shut. The viscometer and stand are finally placed in the bath. The liquid used for the bath is water for temperatures up to 100° C., an oil of high boiling point being employed for higher temperatures. Such an oil should be used as gives off but little vapour at 150° C. To allow for expansion, the bath is scarcely filled up to the level at first, sufficient liquid being added, after warming, to cover the upper bulb of the instrument. The bath is maintained at the desired temperature by the aid of the lamp and a wooden stirrer. Before being placed in the viscometer, the oil is warmed in a can, *y*, to several degrees above the testing temperature (53° for 50° and 165° for 150° C.). The apparatus is then lifted out of the bath for about half a minute to allow the *lower* bulb to cool, and the oil is poured in until the level of the filling mark *f* is reached, the lower bulb being immersed simultaneously. (The object of this is to cause the expansion of the air in the cooled bulb by the heat of the bath, and so prevent the oil flowing through the capillary tube.) This position must be maintained until the oil is 4° higher than the testing temperature, when the viscometer is completely immersed, and allowed to stand until the right degree is reached, the bath liquid being continually stirred. At this point, the taps, *o* and *m*, are opened in the order named, and the time occupied for the exhaustion of the oil up to the mark, *g*, is noted. If the oil under test is not clean and free from water, it must be filtered and dried at 110° C. The apparatus is cleaned with benzine and ether, and it must be carefully dried before it is again used. In fixing the standard by means of the glycerine solution, the lower bulb is immersed in warm water, as in applying the test to oil, to keep the glycerine out of the capillary tube.

Comparison of Künkler's and Engler's Instruments.—The following tables show the relation between results obtained with the Künkler and the Engler instruments, and an approximate idea can be obtained of the behaviour of a sample in Engler's viscometer when the sample itself is too small to be tested, by dividing the results obtained in Künkler's tester as compared with glycerine (not the rate of flow in seconds), by 1·50 for 20° C.; 1·33 for 50° C.; and 8·40 for 150° C.

Oil	Künkler's.						Engler's.					
	Viscosity.						Viscosity.					
	Rate of Flow in Seconds at			Compared with Glycerine Solution at 20° C. (1·110 sp. gr.) 66 seconds = 1.			Rate of Flow in Seconds at			Compared with Water at 20° C. 54 seconds = 1.		
	20° C.	50° C.	150° C.	20° C.	50° C.	150° C.	20° C.	50° C.	150° C.	20° C.	50° C.	150° C.
1. Refined Rape Oil,	1220	380	...	18·48	5·76	...	660	224	...	12·22	4·15	...
2. Cod-liver Oil, . .	760	262	...	11·51	3·97	...	430	165	...	7·96	3·06	...
3. Light American Machine Oil, 0·905,	905	215	...	13·71	3·26	...	475	140	...	8·80	2·59	...
4. Light Russian Machine Oil, 0·908, .	4320	595	...	65·50	9·01	...	2340	355	...	43·33	6·57	...
5. Light American Cylinder Oil, . .	...	...	750	...	...	11·36	...	...	75	...	...	1·39
6. Dark American Cylinder Oil, ...	...	...	1005	...	...	15·23	...	...	95	...	...	1·76
7. Valvoline Cylinder Oil, ...	...	...	885	...	...	13·41	...	...	85	...	...	1·57

Arvine's Viscometer.—The Arvine viscometer, for testing cylinder oils, consists of a coiled copper tube of small diameter, passing through a bath of boiling water. The lower end of the tube is provided with a small stop-cock and jet, while the upper end communicates with a funnel which holds the oil.

Barbet's Viscometer.—In this apparatus, the oil flows through an annular space formed by fixing an iron rod 4 millimetres in diameter, in the centre of a brass tube of 5 millimetres internal diameter. Increased resistance to the flow of the liquid is thus created, and the apparatus is said to be more sensitive than an ordinary jet viscometer.

Lepenau's "Leptometer."—In this instrument[1] (Fig. 242)

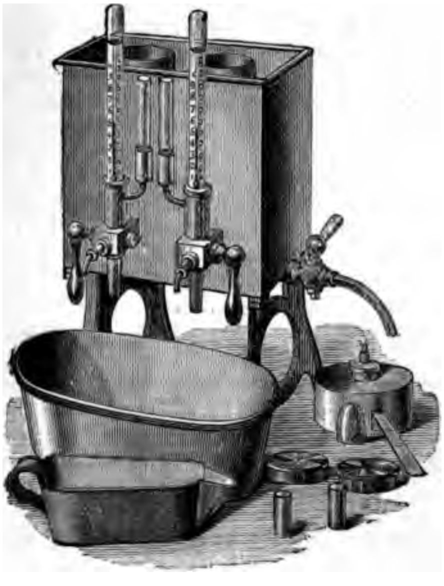

Fig. 242.

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[1] German patent, No. 23662.

there are two similar metallic cylinders placed side by side in a water bath and terminating below in stop-cocks. Three sets of interchangeable jets are provided for attachment to the stop-cocks. A standard oil is placed in one cylinder and the oil to be tested in the other, and a pair of jets which will deliver the oils in drops at a suitable speed having been fitted to the stop-cocks, the oils are allowed to run out, and the number of drops falling from each cylinder, between two coincidences of dropping, is noted. The number of drops falling from the jet is not, however, necessarily a measure of the quantity of oil, since the size of the drop varies with the nature of the oil.

Gibbs' Viscometer.—The Gibbs viscometer, which is used on the Chicago, Milwaukee, and St Paul Railroad, has been described in *Engineering Chemistry* by H. Joshua Phillips (2nd. ed., 1894, pp. 244 and 245). The objects which the inventor is stated to have had in view in designing this apparatus, are as follows:—

> (1) To have a large body of hot oil as a bath surrounding the oil to be tested, in order to keep the latter at a perfectly even temperature. (2) To apply a forced circulation to the bath by means of a double action pump, to insure equality of heat in all parts. (3) To deliver the oil to be tested at the orifice under a constant head. (4) To supply convenient means for accurately measuring the temperature of the oil.

The oil bath is of copper, with a heavy, brazed bottom. This contains a cylindrical inner chamber with a conical bottom terminating in a gauged aperture one-sixteenth of an inch in diameter. Into the inner chamber fits an inverted reservoir holding the oil to be tested. A tube extending nearly to the bottom of the inner chamber, serves to determine the head of oil. Through this tube a thermometer is inserted. The bath is heated by means of a lamp placed beneath a heating chamber, which is in communication with the bath, and with a small double-action force pump. Circulation of the oil in the bath is promoted by the use of suitably-placed deflector plates.

Bubble System.—One method of ascertaining the viscosity of oils, which has been proposed, is to note the time occupied in the ascent of a bubble of air through a given column of the oil. Professor Mills has modified the system by using hollow glass spheres, but without obtaining promising results.

Viscometers of Napier and Cockrell.—The paddle viscometers of Napier and of Cockrell, are based upon the principle of taking the speed of a paddle wheel revolving in the oil, as a measure of the viscosity. Mr. Napier has also employed a series of concentric rings attached to a revolving plate, A (Figs. 243 and 244) and working in the spaces, C, between similar rings, B, on a fixed plate. The revolving gear is supported on an upright, D, and a jacket, E, encloses the oil vessel. Napier has, in another arrangement, employed a hollow vertical drum revolving in a slightly larger cylinder containing the oil.

Doolittle's Viscometer.—A recent arrangement is the *torsion* viscometer proposed by Doolittle.[1]

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[1] *Journ. Am. Chem. Soc.*, 1893, xv., 173, and *Journ. Soc. Chem. Ind.*, 1893, 709.

In this apparatus, as shown in Fig. 245, a steel wire, supported by a frame, is attached to the upper end of a rod fixed vertically in the centre of a graduated horizontal disc, by means of which the torsion sustained by the wire is measured. To the lower end of the rod, a cylinder 2 inches long and 1½ inch in diameter, is attached by a stem. The cylinder being immersed in the oil to be tested, the disc is adjusted to register exactly zero, showing there is no torsion on the wire, and is then supported in that position while the oil is brought to the temperature required for the test. When this temperature is attained, the milled head at the upper end of the wire is rotated through 360°, and the disc being released from its supports, is drawn round by the torsion of the wire. If there were no resistance, the disc would revolve back to zero, and the momentum would carry it 360° in the opposite direction; but the resistance offered by the oil to the rotation of the

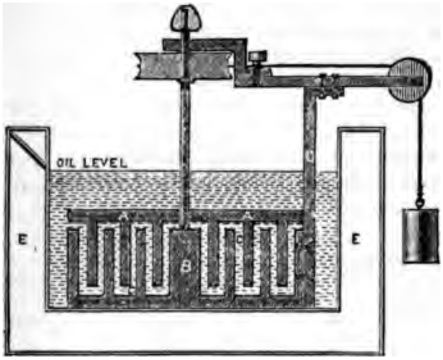

Fig. 243.

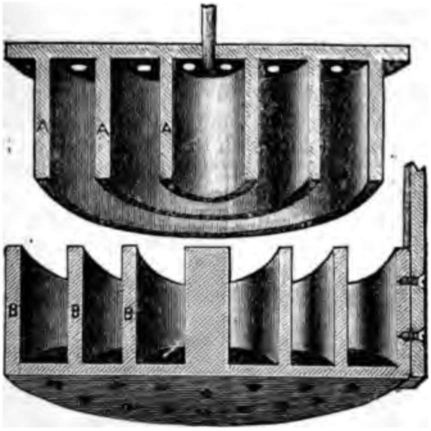

Fig. 244.

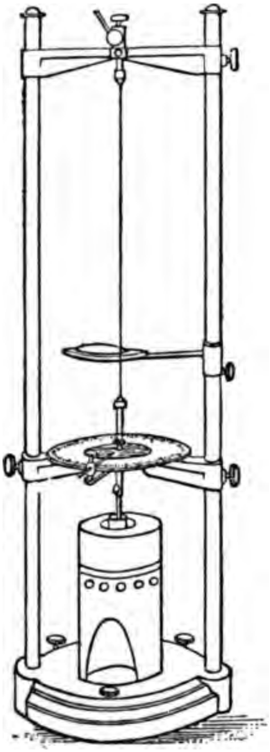

Fig. 245.

cylinder, which resistance is directly proportional to the viscosity of the oil, prevents this complete revolution, and the simplest way of expressing the viscosity, is by the number of degrees of retardation between the first and second complete arcs described by the disc.

A circular issued by the maker of the instrument contains the following additional particulars:—

"For example, suppose we twist the wire 360° and release the disc so that rotation begins. In order to obtain an absolute reading to start from, which shall be independent of any slight error in adjustment, we ignore the fact that we have started from 360°, and take as our first reading the end of the first swing. Ignore the next reading, which is on the other side of the 0 point, as it belongs in common to both arcs. Take the third reading, which will be at the end of the second complete arc, and on the same side of the 0 point as the first reading. The difference between these two readings will be the number of degrees retardation caused by the viscosity of the oil. Suppose the readings are as follows:—

First reading,	right hand,	355·6°
Second ,,	left hand, ignore,	
Third ,,	right hand,	338·2°
		17·4° retardation.

"In order to secure freedom from error, we make two tests—one by rotating the milled head to the right, and the other to the left. If the instrument is in exact adjustment, these two results will be the same; but if it is slightly out, the mean of the two readings will be the correct reading. In order to overcome the variations in different instruments, each one is standardised against pure cane sugar solutions, after the manner proposed by Mr. Babcock, and the viscosity is expressed in the number of grammes of pure cane sugar contained in 100 c.c. of the syrup at 60° F., which will give the retardation designated at 80° F. These readings are obtained by making a number of solutions containing known amounts of pure cane sugar and determining the retardation of each. A curve is then mapped out on a piece of plotting paper, the number of grammes of sugar in 100 c.c. of the different syrups representing the abscissæ, and the degrees of retardation, the ordinates. This curve enables us to interpolate the value of each degree of retardation in terms of pure cane sugar, and in this way a table of viscosities is drawn up and furnished with each instrument. This table renders the results obtained by different instruments strictly comparable."

The Value of the Viscosity Test—Friction-testing Machines.—In the instruments already described, no attempt is made to reproduce the conditions under which lubricating oils are employed, and the results which they furnish are of a purely arbitrary character. Nevertheless, the author is of opinion that the viscosity of a mineral lubricating oil is the best guide to its lubricating value, the consumer being thus enabled to select, from time to time, oils similar to those which he has found by practical experience to give the most satisfactory results. The subject of the comparative values of results obtained with a viscometer and with a friction-testing machine has been discussed by the author in a paper read before the Society of Chemical Industry,[1] from which the following remarks are substantially reproduced:—

In order fully to realise the importance of the determination of viscosity in mineral lubricating oils, and the value of a good test of viscosity, it will be necessary briefly to consider the laws of the friction of fluids, as applicable to the circumstances under which oils are employed in the lubrication of machinery. These laws, as is well known, differ very materially from those which govern the friction of solids, though it is important to bear in mind that the friction in the case of the lubricated rubbing surfaces of machinery in motion is usually a compound friction made up of the friction of solids, and of the friction of fluids, in proportions varying according to the circumstances of the case.

The friction of solids in motion is of two kinds—viz., sliding friction and rolling friction. It is, however, only the former class of solid friction which now demands our attention. In sliding friction, the magnitude of the resistance is, up to the point of abrasion, dependent upon the character of the surfaces, and proportional to the force with which they are pressed together, though in the case of lubricated surfaces, the resistance may be principally due to the adhesion when the pressure is very low. In fluid friction, on the other hand, whether of liquids or gases, the resistance is proportional to the area and velocity of the surface exhibiting it, and to the density and viscosity of the fluid. As Professor Thurston[2] expresses it: "Fluid friction is therefore the friction of adjacent bodies of fluid in relative motion, and is due to the formation of small whirls or large eddies in the two bodies, the production of which absorbs energy from the flowing mass. The friction of the fluid finally extinguishes this energy of eddy-motion, converting it into heat, and raising the temperature of the mass by the introduction of the heat equivalent of the mechanical energy thus destroyed. The resisting property which thus effects this conversion, and which is the cause of fluid friction, is termed viscosity. . . . In the case of limpid liquids and gases the resistance is of kinetic character, rather than one due to intra-molecular action; but the flow of viscous liquids is evidently greatly influenced by their molecular constitution."

In most cases, as already stated, the friction of the lubricated surfaces of machinery is a compound one, but in some instances, it is found practicable to float the moving part in the lubricant, and under such circumstances, the resistance is due only to fluid friction. On the other hand, in the case of slowly-moving heavy machinery, the resistance is usually largely made up by the friction of solids. It follows from what has been said, that in theoretically perfect lubrication, the resistance would be independent of the pressure, and the nearer we can approach to this condition in practice, the better.

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[1] *Journ. Soc. Chem. Ind.*, v. (1886), 121.

[2] *A Treatise on Friction and Lost Work in Machinery and Millwork.* By Robert H. Thurston, A.M., C.E., New York, 1885.

The more viscous the lubricant and the stronger the attraction taking and holding it between the moving surfaces, the greater the pressure which can be sustained; but unnecessarily high viscosity creates unnecessary fluid friction, and the viscosity of the lubricant should therefore be in proportion to the pressure. In other words, the lubricant should have only just sufficient viscosity to keep the moving surfaces apart, under the maximum pressure. The amount of viscosity required in a lubricant, therefore, varies according to the circumstances under which the lubricant is to be used. It is obviously dependent not only upon the load carried upon a given area, but also upon the fit of the bearing surfaces, and upon the character of the motion. Thus, the axles of railway trucks are subjected to pressures greatly in excess of the load carried, when the vehicle is passing over inequalities in the permanent way. It has also been found that the power required to drive machinery which has been lubricated with an oil sufficiently viscous to keep the moving surfaces apart, is diminished when a more fluid lubricant is substituted.[1] It is true that this diminution of resistance is accompanied with greater wear of the metallic surfaces, and greater expenditure of the lubricant, but in the case of factories provided with insufficient motive power, it may be preferable to have less theoretically perfect lubrication.[2] In a cotton mill, for instance, the use on the spindles, of a very slightly better, in the sense of a more viscous, lubricant, though increasing the fluid friction between the bearing surfaces of each spindle only to an infinitesimal extent, might arrest the motion of the whole machinery of the mill. Largely for these reasons, no doubt, the many ingenious machines of Ingram and Stapfer, Thurston, Woodbury, and others, designed to test the lubricating value of oils, have not hitherto given results of much practical value. With some of these machines strictly comparative data of lubricating power under the conditions present in the machine can be obtained; but as these conditions frequently differ from those presented in actual practice, the deductions drawn from the data may be misleading.

Professor Thurston himself admits that the use of the testing machine to determine the relative friction-reducing power and wear, and the endurance of oils, as data for use in the solution of the commercial problem, will often be found to involve some difficulties.

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[1] It has been well said that many an engineer wastes tons of coal in an attempt to save gallons of oil.

[2] Mr. Thurston points out that the measure of the coefficient of friction alone, is not always a gauge of the value of an oil. A low coefficient is sometimes found to co-exist with serious wear, and even low friction and a cool journal may be accompanied by wear. With very light pressures and high speeds, as with fast-running spindles, light mineral oils sometimes give low friction, and yet produce rapid wear. Mr. F. W. Arvine found that a cotton spindle, after running for some time at a speed of 6,500 revolutions per minute with a fluid oil, lost as much as one-tenth gramme in weight.

These difficulties arise, however, not from faults of the method, but, as he says, from the exceedingly great uncertainty often existing as to whether the conditions of test are precisely those of use. He adds that a good testing machine may be relied upon, if properly handled, to give accurate data; but it can rarely be made equally certain that the same conditions can be permanently retained when the lubricant is put in service. Satisfactory approximations may, however, in his opinion, readily be secured, with careful supervision and ordinary skill, for all cases in which the machinery is well proportioned, in good order, and well cared for. Mr. Thurston further remarks that experiments made upon the nicely-fitted journal of a testing machine are not conclusive as to suitability of a lubricant for use on a similar journal which is not well fitted. The latter, bearing only in spots, or along lines of contact, is subjected, on such surfaces of contact, to pressure which may be enormously greater than that affecting the same journal when wear or refitting has given it a good fitting, and the best lubricant is therefore one adapted to such intense pressure. Could the magnitude of this extraordinary pressure be known, a good testing machine would determine which of any collection of oils is best fitted to sustain it. The testing machine determines the behaviour of oils upon its own journals; if those on which the lubricant is to be used are similar, its behaviour will then be the same. While the machine does not usually serve to select oils for badly made surfaces, it exhibits the intrinsic qualities of the oils tested; and every mechanic and engineer endeavours to get all journals into as good condition as those of the testing machine, and thus fit them to do good work with good oils. Mr. Thurston also expresses the opinion that in order to determine precisely what oils are adapted to any special purpose, or to ascertain for what use any oil is best fitted, it is necessary to make an examination of the lubricant while it is working under the specified conditions. That is to say, the oil should be put upon a journal of the character of that on which it is proposed to use it, subjecting it to the pressure proposed, and running it at the speed that the journal is expected to attain; its behaviour will then show conclusively its adaptability to such an application. Valuable papers on the subject of the mechanical testing of lubricating oils have been contributed by Professor Ordway and Mr. C. J. H. Woodbury.[1] The experiments conducted by Professor Ordway, in association with Mr. Atkinson, had for their object to determine, among other points, the extent to which spindle oils in common use, were liable to spontaneous combustion when absorbed by cotton-waste or other similar material, as well as the temperature at which they evolved inflammable vapour. But the investigation is referred to here, chiefly because these gentlemen report that three machines—two American and one English—which they had obtained with the view of testing the lubricating power of the oils under examination, furnished no satisfactory results; and it was accordingly found necessary to substitute for these machines an ordinary spinning frame, with a thermometer applied to each spindle, the heat evolved being regarded as a measure of the friction. Mr. Woodbury's papers are largely devoted to a description of the results obtained with the well-known testing machine of which he is the inventor. In the first paper, it was pointed out that friction varies with the area, because the adhesiveness of the lubricant is proportional to the area, and the resistance due to this cause is a larger fraction of the total mechanical effect with light, than with heavy pressures. Accordingly, as the results of the preliminary experiments indicated that the coefficient of friction varied with the conditions, it was found necessary to reproduce those of actual working, to determine the value of a lubricant for specific purposes.[1] In Mr. Woodbury's second paper, the results obtained with a modified form of apparatus, constructed to carry pressures up to 40 lbs. per square inch, were given. The experimental data contributed by Mr. Woodbury, supplemented by those reported by Mr. Beauchamp Tower in this country, constitute a comprehensive series, since Mr. Tower operated at great pressures (100 lbs. to 625 lbs. per square inch), though with a special method of lubrication (the oil-bath system); but in the discussion which followed the reading of Mr. Woodbury's second contribution, it was pointed out by Mr. F. W. Arvine, chemist of the Thompson and Bedford Company of New York (manufacturers of lubricating oils), that the agreement between the results yielded by ordinary testing machines and those obtained in actual practice was unfortunately very small.[2]

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[1] *Proceedings of the Semi-annual Meeting of the New England Cotton Manufacturers' Association*, held at Boston, U.S., 30th October, 1878. Report by John M. Ordway, representing the Department of Industrial Chemistry of the Massachusetts Institute of Technology, and Edward Atkinson, representing sundry insurance companies. *Transactions of the American Society of Mechanical Engineers*, Nov. 1880, and Nov. 1884. "Measurements of Friction of Lubricating Oils," by C. J. H. Woodbury, of Boston, Mass., Inspector Factory Mutual Assurance Companies.

As the Pennsylvania Railway Company have paid considerable attention to the testing of lubricating oils, it is instructive to find that in 1885 the opinion of Dr. Charles B. Dudley, chemist of the company, who had studied the subject of lubricants during the preceding ten years, was that the problem of diminishing the loss due to friction was complicated, and not well understood. The author has not had the opportunity of working with the machine of Professor Thurston or that of Mr. Woodbury, but some years ago he was engaged for many months in testing lubricating oils with the Ingram and Stapfer machine, and he found it impossible to obtain any results that were thoroughly satisfactory from a practical point of view.

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[1] The working pressure in Mr. Woodbury's earlier experiments was 5 lbs. per square inch, and the speed 500 revolutions per minute, these conditions corresponding with the velocity and pressure of a Sawyer spindle running at 7,600 revolutions per minute, with a band tension of 4 lbs. Mr. Woodbury stated that the intermittent pressure on the wrist-pin of a locomotive, amounted to as much as 3,000 lbs. per square inch. According to Professor Thurston, the maximum pressure on the crank-pins of heavy engines is 1,200 lbs. per square inch, and under the pivots of drawbridges, sometimes as much as 9,000 lbs. per square inch.

[2] Mr. Arvine found it necessary to use for the testing of spindle oils, a frame of spindles, such as may be found in a cotton mill, and for the testing of heavier oils, a railway-waggon axle, of the usual construction, capable of being loaded with the weight commonly carried. Both pieces of apparatus were driven at the ordinary speed, and were fitted with sensitive dynamometers and thermometers.

In studying the records of the experiments made in the testing of lubricating oils with the various machines which have been devised for the purpose, one cannot fail to admire the ingenuity and patience with which the results have been arrived at. It must, however, be obvious that the indications afforded by testing machines may in the present state of our knowledge of the subject be wholly misleading, and it is this fact which has led the author to attach great importance to the adoption of a good system of determining the viscosities of oils. To his mind indeed, the most valuable result of the experiments made with testing machines has been the demonstration of the close relation which exists between viscosity and lubricating power. Professor Thurston has pointed out that this close relation is well shown in the curves, which exhibit graphically the results obtained by Mr. Waite.[1]

Mr. Woodbury states that, within a close approximation, the lubricating qualities of an oil are inversely proportional to its viscosity; that is, that the friction decreases with the cohesion between the particles of oil. Although in succeeding remarks, Mr. Woodbury somewhat qualifies the statement quoted, there is little doubt that the determination of the viscosity of an oil affords the most valuable test of lubricating properties that we have at our disposal. There may be an advantage in testing the oil by using it under conditions to which it will be subjected in actual practice, but it is admittedly exceedingly difficult to determine what these conditions are, especially in some cases, and still more difficult to reproduce them with certainty. On the other hand, if a certain oil has given satisfactory results under given conditions of fit, or want of fit, of bearings, pressure, speed, and temperature, it may be predicted with tolerable certainty, that another oil of the same nature, having a similar viscosity, will yield equally good results.

Professor Thurston, who has devoted much study to mechanical methods of testing, gives[2] the following as the characteristics of an efficient lubricant:—

(1) Enough "body" or combined capillarity and viscosity to keep the surfaces, between which it is interposed, from coming in contact under maximum pressure.

(2) The greatest fluidity consistent with the preceding requirement—*i.e.*, the least fluid friction allowable.

(3) The lowest possible coefficient of friction under the conditions of actual use —*i.e.*, the sum of the two components, solid and fluid friction, should be a minimum.

(4) A maximum capacity for receiving, storing, transmitting, and carrying away heat.

(5) Freedom from tendency to decompose or to change in composition by gumming or otherwise, on exposure to the air, or while in use.

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[1] These results were reported in the *Proceedings of the New England Cotton Manufacturers' Association*, 1880.

[2] In his work on *Friction and Lost Work in Machinery and Millwork*, N.Y., 1885.

(6) Entire absence of acid or other properties liable to produce injury of materials or metals with which they may be brought in contact.

(7) A high temperature of vaporisation, and a low temperature of solidification.

(8) Special adaptation to the conditions as to speed and pressure of rubbing surfaces, under which the unguent is to be used.

(9) Freedom from grit and from all foreign matter.

MacNaught's Tester.—The MacNaught tester was invented about 1838,[1] and is shown in Fig. 246. It consists of a circular plate, E, on a spindle, A, capable of being revolved by an endless cord running on a pulley, D. On the plate E rests a plate F, having a stud, *a*, which, when the plate is turned, engages with a pin on an arm attached to a weighted lever, G H. The instrument is fixed to a table by means of the clamp, B, C. A few drops of the oil are placed on the plate E, and the apparatus is then set in motion at the proper speed. The plate F thus tends to revolve, and through the stud, *a*, to alter the position of the lever, G H, but this is prevented by moving the adjustable weight, J. The extent to which the weight is moved in establishing equilibrium, is a measure of the viscosity of the oil, and hence this instrument in its original form might more properly be described as a viscometer.

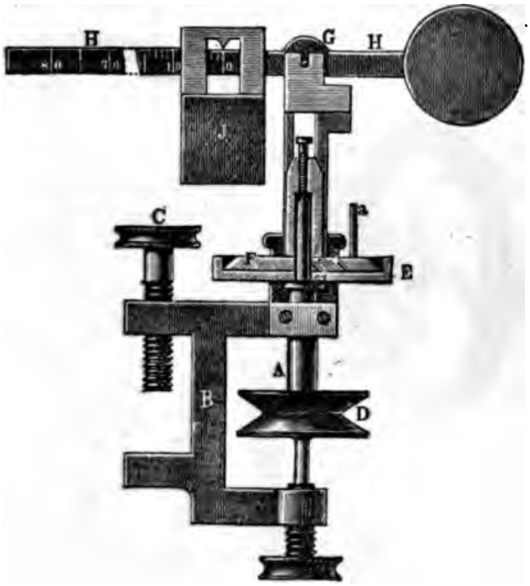

Fig. 246.

Duske's Modification.—Duske,[2] has introduced a modification in which adjustable pressure is applied to the plate F, by means of a lever and sliding weight.

Woodbury's Tester.—In the tester introduced by Woodbury,[3] which has been described as a modification of MacNaught's, the load is applied by direct weights. The upper plate is surmounted by a hollow chamber divided into channels through which a current of water circulates, and is further covered with an ebonite hood, lined with eiderdown to prevent access of heat from the outside. Four upright pillars on the upper plate carry, by a ball and socket joint, an axle moving in two bearings and supporting a crossbeam which bears the load. The weights are under the table on which the machine stands, on a platform suspended by stirrups from the crossbeam. In order to equally adjust the wearing surfaces of the two discs, the axes of the upper and lower spindles do not coincide but are on parallel lines about one-eighth inch apart. A thermometer indicates the temperature in the upper disc, and the rate of feed of the oil under test, is observed by using a glass feed tube. To minimise torsional friction in the upper axle, the bearings are movable and are revolved in opposite directions. A counter records the number of revolutions, and a dynamometer registers the amount of friction. In cases where the friction would be too great for the dynamometer, a pair of compound levers is employed to reduce the stress to one-fifth the actual friction, and in such cases, the reading of the dynamometer must be multiplied by five.

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[1] See the *Mechanics' Magazine*, 1838, No. 774, and *Dingler's polytech. Journ.*, 1862, clxiv., 18.

[2] *Dingler's polytech. Journ.*, 1862, clxiv., 19.

[3] *Engineering*, 1884, xxxviii., 532.

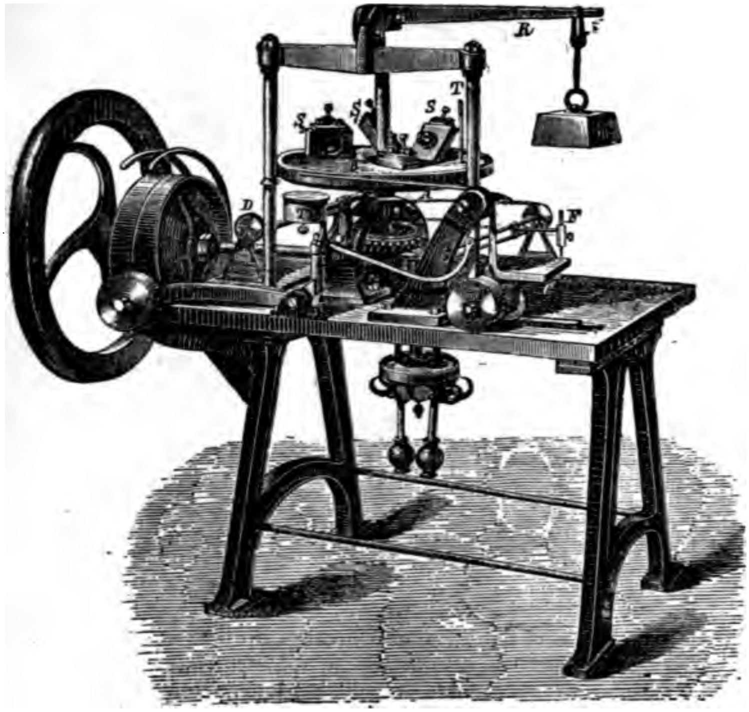

Fig. 247.

Deprez and Napoli's Tester.—The apparatus of Deprez and

Napoli[1] was patented in France in 1877. It consists of a horizontal flat polished disc, A (Fig. 247), mounted on an axle set in motion by bevel cog-wheels driven by a pulley, D, and carrying a second disc, B, by means of three bronze blocks, S, S$_1$, and S$_2$, inclined towards A at an angle of 30°, and having a contact surface of 10 square centimetres each, so that the pressure exerted on B by a weighted lever, R, is equally divided among them. The friction between A and S, S$_1$, S$_2$ tends to rotate B, the tendency varying inversely with the lubricating power of the oil under test. To the edge of B, is attached one end of a steel ribbon, the other end being fastened to a pivoting pulley. To this pulley is attached a vertical pendulum, P, which is raised towards the horizontal by the rotation of B. The movement of P causes a reciprocating motion of a small wheeled trolley, C, through the medium of a pin and slot. The trolley carries a piece of paper, on which a curve showing the movement, is marked by a pencil, F, fixed to a travelling arm. The speed of this arm is governed by the number of revolutions of the principal axis—*i.e*, of the plate A. The curves show the degree of friction at the rate of speed adopted, and, if quadrated, will give the total energy absorbed by the machine. To save the trouble of calculating out the results of the diagrams, the inventors have affixed to the machine a totaliser, consisting of a roller, T, kept in position against the edge of a disc concentric with A, by means of a spring. Its axle is capable of any degree of inclination in a fixed vertical plane, and is so connected with the pendulum, P, as to make with the horizontal, the same angle as is made by the pendulum with the vertical. The number of revolutions of the roller as recorded by the totaliser, is proportional to the force, in kilogrammes, of the friction between the two plates. Five

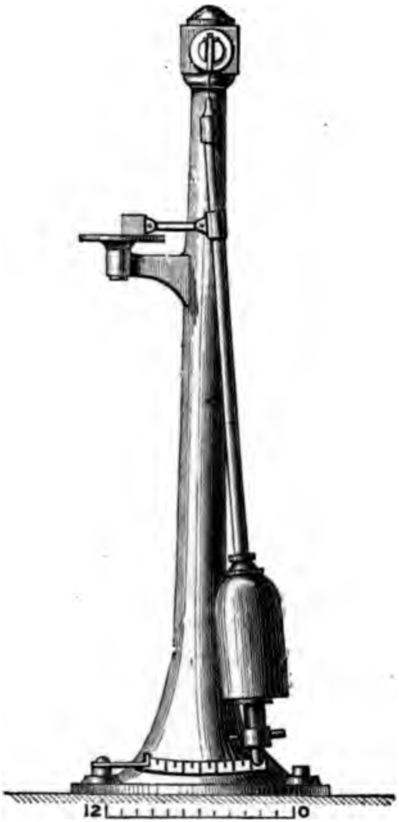

Fig. 248.

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[1] *Dingler's polytech. Journ.*, 1877, ccxxvi., 30.

grammes of oil is used for each test, and to ensure the regularity of speed necessary for the exact comparison of the lubricating properties of different samples, a speed governor is fixed below the apparatus.

Bailey's Tester.—In Bailey's pendulum tester (Fig. 248), designed for testing oils which are to be used for clocks and watches or other light work, a single drop of the oil is placed on a small disc of brass linked to a pendulum as shown, and resting on a disc. The pendulum is set in oscillation over a graduated arc, and the viscosity is measured by the time which is occupied in bringing it to rest.

Thurston's Tester.—Among the mechanical testers aiming at the examination of the oil under conditions closely approximating to those in actual practice, the inventions of Professor R. H. Thurston are of particular importance.[1] Figs. 249 and 250, show one form of the Thurston tester. The lubricant is placed on a journal, F, carried on the extremity of a shaft, A, sustained by journals, B, on a stand, D E, and driven by a pulley, C. The shaft is driven at a speed corresponding with the work which the lubricant is to do, and has a counter at the end to indicate the number of revolutions. The journal, F, is grasped by bronze bearings, G G¹, pressed together by a spring, adjusted by a screw, K K¹, and having its pressure indicated on a scale by a pointer, M. A thermometer, Q, indicates the heat

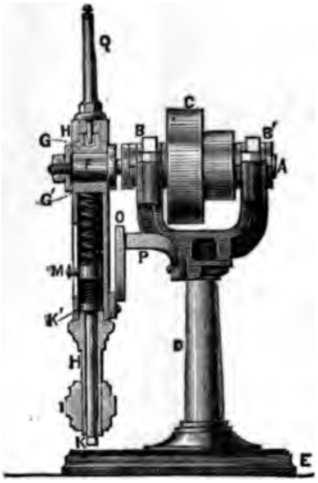

Fig. 249.

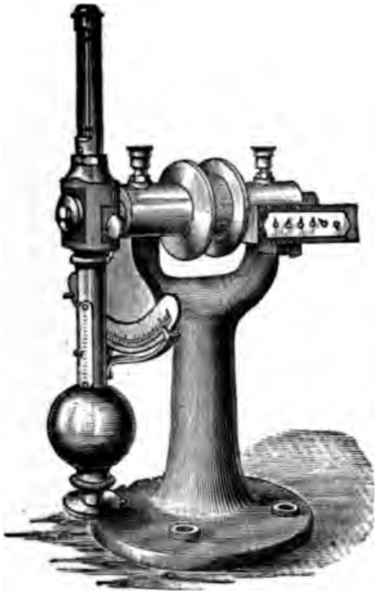

Fig. 250.

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[1] See Thurston's *Treatise on Friction and Lost Work in Machinery and Millwork*, New York, 1885; and a paper read by Mr. W. H. Bailey, before the Manchester Association of Employers, Foremen, and Draughtsmen, Manchester, 1878.

produced during the test. The brasses and spring are carried by a pendulum, H, weighted at I, so that the maximum friction of the *dry smooth* bearing will swing it into a horizontal position. The pendulum carries a pointer, O, traversing an arc, P, which is so graduated, that by dividing the reading by the pressure indicated by the pointer, M, the coefficient of friction when the lubricant is placed on the bearing, F, may be found. In Professor Thurston's work, the theory of the working of this machine is fully discussed. The journal is cleansed, after each test, with alcohol, gasoline, or benzine, but the effect of the lubricant is often felt in succeeding tests, long after starting with a new lubricant. Steam cylinder lubricants may be tested by heating the bearing to the proper temperature. Owing to the good work done by his first machine, Professor Thurston devised a modification especially adapted for railway work, and Fig. 251, shows the "New Zealand Railways" pattern of his *recording* tester, manufactured by Messrs. W. H. Bailey & Co., of Salford. In principle, the machine resembles that described above. The shaft has three different sizes of pulleys for driving it, and the brasses are cast hollow, as first proposed by G. A. Hirn, so that water may be passed through them to keep the bearing at a uniform temperature. The oil is fed to the journal by means of oil cups, and a key and nut are provided for instantly relieving

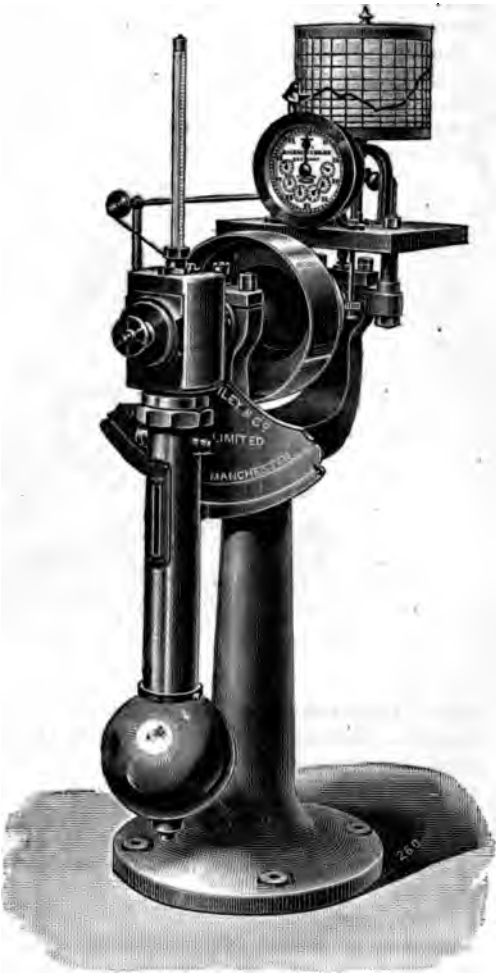

Fig. 251.

the journal of the pressure of the helical spring. The automatic recorder is an improvement due to Lux. The pendulum has an arm which raises and depresses a slide carrying a pencil. The pencil bears against a cylinder carrying a squared paper surface, and revolving once for each 100,000 revolutions of the journal. The diagram is thus drawn to a scale of five-sixteenths of an inch for every 1,000 revolutions.

Ingram and Stapfer's Tester.—In the Ingram and Stapfer tester (Fig. 252), a definite quantity of the oil, measured from a bottle or tube, or by drops, is placed on the bearing, the pressure on which is produced in the manner shown in the figure, and the shaft is driven at about 1,500 revolutions per minute. When the temperature produced by the friction has reached 200° F., as indicated by the thermometer, the machine is stopped and the total number of revolutions since the commencement of the test is read off from the counter, the value of the lubricant being gauged from this result.

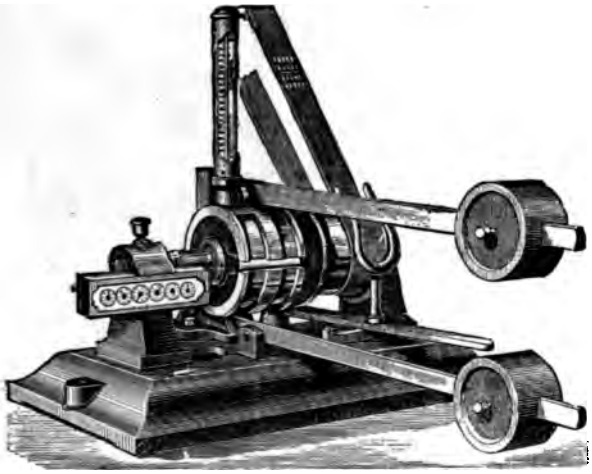

Fig. 252.

French Tester.—The friction tester employed by the Paris, Lyons, and Mediterranean Railway Company (Figs. 253 and 254), exhibited in 1878, has the advantage of subjecting the oils under test to similar conditions to those which they have to undergo in actual work on the railway, and indicates the behaviour of the oil under the varying speeds of an actual pair of railway wheels, as to resistance, rate of consumption, and rise of temperature in the grease boxes. On a firm foundation of masonry, is erected an iron frame, A, A, in which is mounted a driving axle, B, carrying a pair of wheels, C, C, at the usual rail-distance apart. An ordinary pair of truck wheels, D, D, rest on these, the ends of the axle, E, running in bearings fitted with grease boxes of the usual type. The box castings carry a spring, and ter-

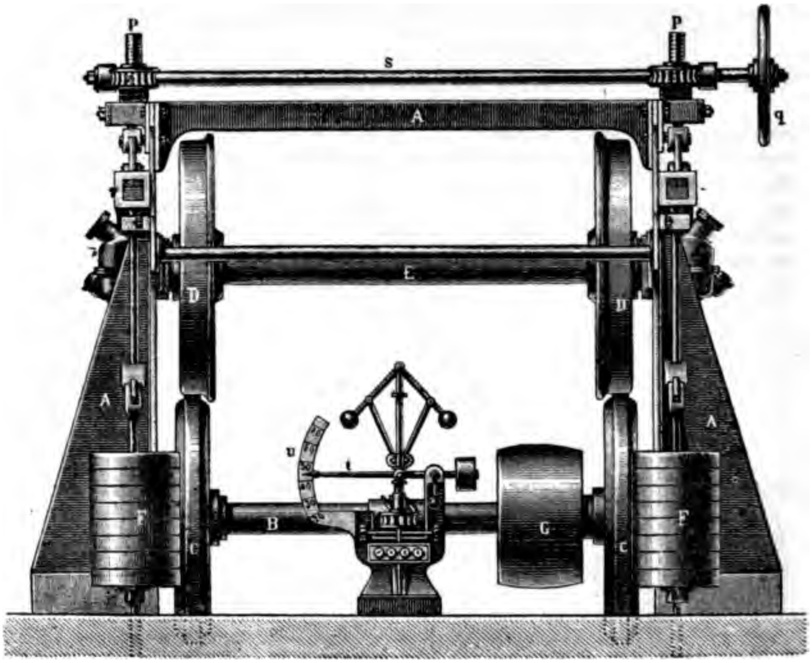

Fig. 253.

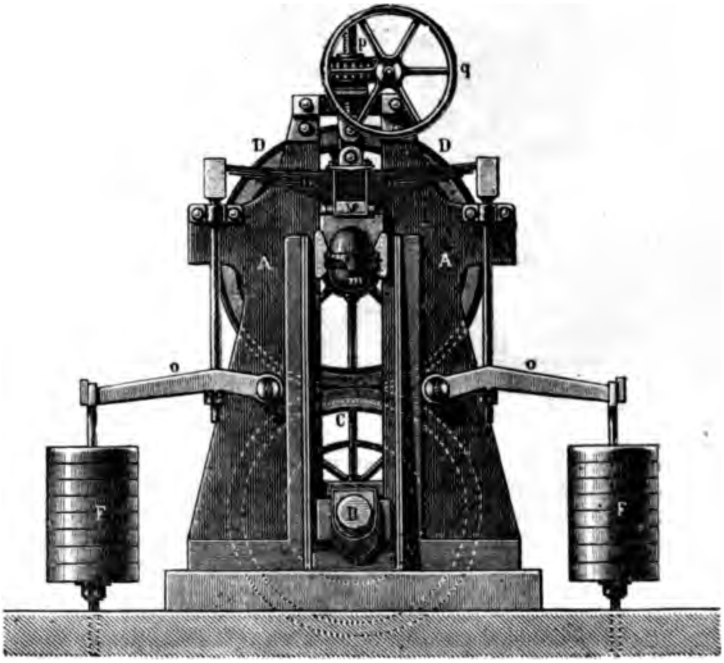

Fig. 254.

minate at the top in a screw, P. The springs can be loaded to any required degree by weights, F, suspended from lever arms, *o*, *o*, bearing on perpendicular rods carried down from the extremities of the springs. The wheels, D, D, can be raised or lowered at will by means of screws cut on a cross-bar, *s*, worked by a hand wheel, *q*, and acting on the screws, P, P. The driving axle carries in addition, a drum, G, by means of which motion is imparted to the apparatus, and is fitted with an indicator for recording the number of revolutions. The rate of speed, in kilometres per hour, is shown on a scale, V, by means of a pointer, *t*. In order to still more closely reproduce working conditions, the driving wheels, C, C, are mounted excentrically 2½ mm. (one-eighth of an inch) out of truth, thus producing an equivalent to the vibration of a railway truck. In applying the test, the oil is put into the grease boxes (previously well cleaned), and the upper wheels are raised by the screws clear of the driving wheels, which are then

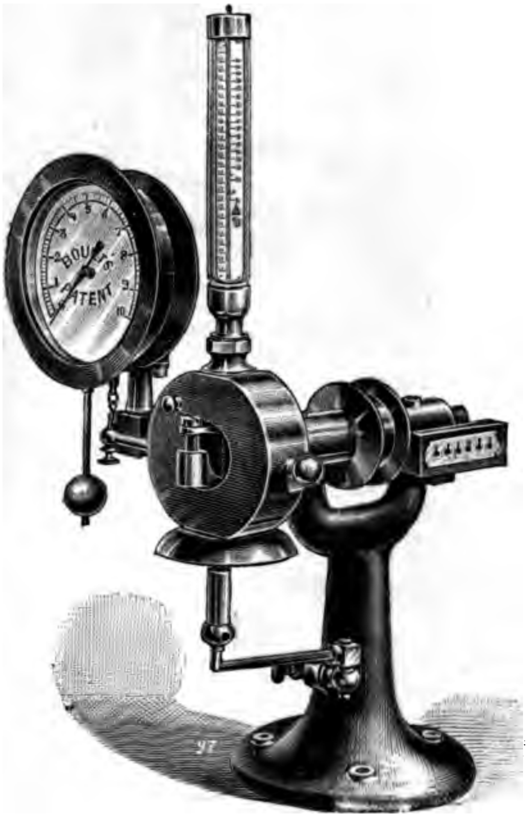

Fig. 255.

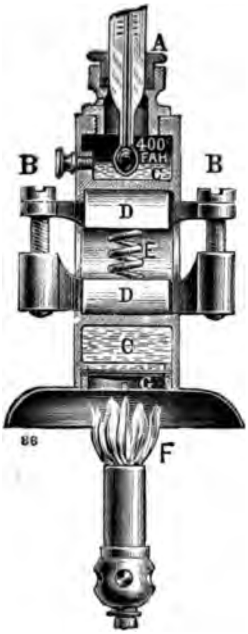

Fig. 256.

put in motion. The upper wheels are then gradually lowered, and the requisite load of weights applied. The oil, which produces the least rise of temperature in the axle boxes under the greatest load and highest rate of speed, is considered the best.

Boult's Tester.—Figs. 255 and 256 represent Boult's cylinder lubricant tester, used for oils required for the cylinders of steam, gas, and hot-air engines, steam hammers, &c. The enlarging friction journal, D, is expanded by a spiral spring, E, adjusted by screws, B, and the friction surfaces to which the oil to be tested is applied, are heated by a cylindrical hot-oil bath, C, to which the necessary temperature as indicated by a thermometer, A, is imparted by a Bunsen burner, F. The tester is run at about 500 or 600 revolutions per minute, or, for quick speed engines, at as much as 1,000. It may be used for temperatures as high as 450° F. or, by cooling the oil bath with ice, &c., may be employed for testing the value of lubricants at low temperatures.

Cold Test.—Lubricating oils are subjected to what is known as the cold test, with a view to ascertaining their power of withstanding low temperatures without solidifying, or depositing paraffin, and the method of applying the test varies with the description of the oil, and, to some extent, with the interpretation of the term by the operator. The cold test of pale oils is usually considered to be the point at which, on a gradual reduction in the temperature, separation of solid hydrocarbons occurs. In applying the test, the oil may be slowly cooled in a small beaker until it commences to become cloudy, but the result will depend in part on whether the oil is stirred, and upon the time occupied in cooling. As some of the more viscous oils contain solid hydrocarbons which resemble vaseline rather than crystalline paraffin, the point at which separation of solids commences is not easily observed, and it is then better to determine the point at which the oil becomes semi-solid, or ceases to flow on inclining the containing vessel. It is important that the temperature of the cooling bath should not be far below that at which separation of solids commences, and it is, therefore, advisable to roughly determine this temperature by a preliminary test. In black oils, the commencement of the separation cannot be seen, and the temperature at which such oils cease to flow is, therefore, taken as the cold test. When the separation of solids is well defined, the test may be applied to a column of the oil an inch and a half in depth in a test tube about an inch in diameter. The tube is plunged in a bath of iced water, or ice and salt, until a thin layer of paraffin congeals on the sides. During the cooling, the oil is stirred with a thermometer, and when congelation commences, the tube is wiped and held in front of a window with constant stirring with the thermometer, until the solid has re-dissolved. The temperature is then noted, and the operation is repeated twice. If the two last tests agree, the temperature may be taken as the cold test.

The melting point of oils which are solid at ordinary temperatures, is often taken in the following manner:—The bulb of a thermometer is coated with the oil and suspended in a beaker of water which is very slowly warmed, the temperature at which the oil, which is of lower specific gravity than the water, begins to flow upwards, being noted as the melting point. This method does not, however, give satisfactory results with oils that are not fairly homogeneous in composition, and, according to the author's experience, a better one is that suggested by Bensemann[1] for determining the point of fusion of fatty acids. This consists in placing a drop of the fused oil in the wide portion of a drawn out tube, and allowing it to become quite solid; then suspending the tube vertically in a beaker of cold water by the side of a delicate thermometer, and applying heat very gradually until the oil begins to flow down the side of the tube into the constricted portion. The temperatures are noted at which (*a*) the oil begins to flow, and (*b*) enters the constricted part. The first is termed the initial point of fusion, and the second the final point of fusion. The author finds that this method gives closely concordant results, and that the difference between the two points is about 2° F.

According to the rules of the New York Produce Exchange, the cold test is determined by cooling the oil in a glass vessel, 4 inches deep and 3 inches in diameter, in a refrigerator. A thermometer is placed in the centre of the oil and another in the refrigerator, and, if the oil is still liquid when the thermometers both record a specified temperature, the cold test is considered satisfactory.

Tagliabue's Cold Test Apparatus.—In Tagliabue's cold test apparatus (Fig. 257) the oil cup is contained in a chamber, F, surrounded by an ice chamber, C, with a non-conducting jacket, A. Taps, J, are provided for forcing in warm air when it is desired to raise the temperature of the oil. The oil cup is fitted on a rocking shaft so that the oil may be kept in motion, and the front of the apparatus has a glass window through which the progress of the test may be observed, and the temperature of the oil, as indicated by a thermometer, *d*, noted. Two other thermometers, *d*, are placed in the refrigerator.

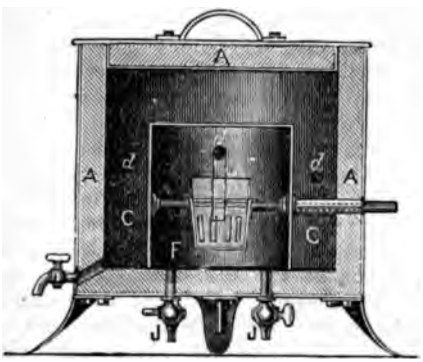

Fig. 257.

Schultze's Cold Test Apparatus.—The cold test apparatus of Schultze of Berlin, adopted by the Prussian State Railways,[2] is fitted with a U-tube 6 mm. in diameter, and graduated in millimetres, to contain the oil to be tested. The U-tube is immersed in a freezing mixture, and is connected with a manometer, by means of which, on opening a pinch-cock, a pressure equal to a height of 50 mm. of water may be applied to its contents. The temperature of the freezing mixture is indicated by a thermometer, and may be adjusted as required, by varying the constituents of the mixture. In applying the test, the U-tube, charged with the oil to a height of 30 mm. in each limb, is immersed in the freezing mixture for an hour, after which it is raised so that the oil surface is above the refrigerant. The pressure from the manometer is then allowed to act, and the rate at which the oil is depressed in the limb connected with the manometer, during one minute, is noted. Several U-tubes containing samples of oil may be cooled simultaneously, and tested one after the other. Dr. Albrecht considers this apparatus unsuited for practical use, and is of opinion that sufficiently accurate results were obtained by the old test used on the Prussian State Railways, which consisted in noting whether the oil at a given temperature, and under a pressure of 30 mm., issued in drops from the 5 mm. nozzle of the test apparatus.

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[1] *Rep. Anal Chem.*, ii., 165; *Journ. Soc. Chem. Ind.*, iv. (1885), 535; also Cameron's *Oils and Varnishes*, 214.

[2] Albrecht, *Dingler's polytech. Journ.*, cclxxxv.

The following are the conditions imposed by the German Railways as to the quality of lubricating oils supplied to them :—

The Royal Prussian Railways.

Mineral Lubricants for all Divisions.—The mineral oils to be used for lubricating rolling stock, steam engines, and tool machinery, must be delivered one half as "summer," and one half as "winter" oil, and comply with the following conditions :—

The *specific gravity* at 20° C. shall lie between the limits of 0·900 and 0·925.
The *viscosity* at the temperatures subjoined shall lie between—

Temperature, . .	20° C.	30° C.	40° C.	50° C.
Highest limit, .	45° ,,	20° ,,	12° ,,	9° ,,
Lowest ,, . .	25° ,,	12° ,,	8° ,,	6° ,,

as recorded by a standardised Engler viscometer, and referred to distilled water at 20° C. The flashing point, tested by the Treumann instrument [see p. 600], shall be above 160° C.

Resistance to Cold.—Winter oil must remain fluid at – 15° C., and summer oil at – 5° C.—*i.e.*, it must ascend a glass tube of 6 mm. internal diameter at a minimum rate of 10 mm. per minute, when subjected to the constant pressure of a 50 mm. water column in Schultze's apparatus [see p. 636]. In addition, the oil must be free from water and acid, have only a slight smell, and completely dissolve in petroleum benzine of specific gravity 0·67 to 0·70. It must not contain any foreign substances, or deposit a sediment, even after prolonged standing; neither may it possess any drying properties—*i.e.*, it must not resinify or dry to a varnishy stratum on long exposure in thin layers to the action of the air. The addition of mineral oils, or distillation products thereof, to rape oil is strictly prohibited in the conditions prescribed for the latter lubricant in the sub-districts of Altona and Berlin.

The Grand Duchy of Baden State Railway.

The mineral lubricating oil must be prepared from petroleum only, and must not contain any other kind of mineral oil (such as coal-tar oil, brown-coal tar oil, or shale oil), or any other oil of vegetable or animal origin (resin oil or fat oil), or solid fat, ceresin (ozokerite), and such like. Only an exceedingly small proportion of solid hydrocarbons (paraffin) is permissible, and the oil must be perfectly free from gum-like impurities ["schleim"], tar, and resin. No brown coloration—

indicative of resin and allied bodies—should result on agitating the oil with an equal volume of sulphuric acid of 1·53 specific gravity. All substances used in refining, such as alkalies, salts, water, and, above all, sulphuric acid, must be absent. The colour must not be too dark, and the oil should be transparent in thin layers; no solid matter must be in suspension, nor should any deposit occur after prolonged standing. The limits of specific gravity at 15° C. are 0·890 to 0·940. On distillation, not more than 10 per cent. by volume should come over below 300° C. (temperature of the oil vapour), and the undistillable residue must not exceed 7 per cent. by volume. The flashing point (production of inflammable vapour) must not be below 160° C., open cup test, or the burning point below 190° C. (oil temperature). The oil should not froth or "prime" at any temperature, neither should it acidify or dry on being heated for twenty-four hours at 100° C. in thin layers exposed to the air. The viscosity of the mineral lubricant must be at least equal to that of rape oil at temperatures up to 50° C., and—with a view to employment in oilers with wicks—must be at least one and a-half times as great as that of rape oil between 30° and 50° C. (measured by Engler's viscometer). At low temperatures, down to 0° C., it must be sufficiently fluid to allow the wick-oilers to act normally. At -5° C. the oil must be still fluid, without exhibiting any separation of solid matter, and must not congeal above - 10° C.

Royal Bavarian State Railways.

The mineral lubricating oils supplied must be almost odourless, and quite free from tar, tar oil, creosote oil, paraffin, acid of any kind (beyond a trace, not exceeding 0·029 per cent.), animal and vegetable fats, or fat oils, and must further have a specific gravity of 0·915 (with a margin, up or down, of 0·005), a flashing point of 190° [method of testing not specified], with an allowance of 10° either way, and a viscosity at 50° C. of 230 to 330 compared with rape oil (100). The viscosity should only diminish slowly between 20° and 150° C. Summer oil should be of relatively higher, and winter oil of relatively lower viscosity between these figures. Shaken up with water, the oil should not show any flocculent matter. On agitation with potash lye of 1·35 specific gravity, and heating to boiling point, the lye should remain colourless and clear, and should not undergo any alteration in volume after repeated shaking. Agitation with sulphuric acid of specific gravity 1·6, and warming on a water bath, should not produce more than a deep yellow (on no account brown) coloration of the acid, nor, on being shaken up with an equal volume of sulphuric acid of 1·4 specific gravity, at an equal initial temperature of 15° C. for both liquids, should the increase of temperature exceed 10° C.—*i.e.*, the temperature should not rise higher than 25° C. Oil which "primes" strongly when heated, will be considered useless. At - 10° C., the oil must flow freely, or be of no greater consistency than thin salve, and must be still of similar appearance at -16° C., without congelation. No separation of paraffin should occur even at the lowest temperatures, and the insoluble residue (solid constituents) must not exceed 1 per cent.

The Hessian Ludwigsbahn Company.

Pure, almost inodorous, mineral oil is required, free from tar, tar oil, creosote oil, paraffin, and acid of any kind, or admixture of any description of animal or vegetable fats or oils. The specific gravity at 20° C. must not fall below 0·900, nor exceed 0·925 for cylinder oil, and 0·915 for axle oil. The minimum flashing point of cylinder oil is fixed at 190° C., and of axle oil at 160° C. [apparatus not mentioned], with burning points of 220° and 180° C. respectively. The congealing points must be as low as possible, and the oils should still flow pretty freely at 0° C. Axle oil should, at - 10° C. (and cylinder oil at - 5° C.), run slowly from a tube 6 mm. in diameter, under a pressure of 50 mm. In applying this test, the oil is to be exposed to the prescribed degree of cold for one hour without being shaken. As regards viscosity, the minimum fixed for axle oil is 8, and for cylinder oil 18 Engler units (water = 1) at 50° C. The tests with water, caustic potash solution, and sulphuric acid, are the same as those prescribed by the Bavarian State railways, as is also the condition referring to priming. The oil should dissolve in petroleum benzine of 0·67 to 0·70 specific gravity, without leaving more than 1 per cent. of residue.

The Main-Neckar Railway.

Pure, double-refined, mineral oil is required, of a green or brown colour, free from salts, acid, resins, and tar oil, leaving no residue when filtered, and having the requisite lubricating power to obviate any tendency to heating of the bearings of locomotives or cars, even at the highest speeds. The range of specific gravity permissible is between 0·875 and 0·910, and no evolution of inflammable vapour should occur below 170° C., nor should the oil congeal above −5° C. On being treated with an equal volume of sulphuric acid of 1·45 specific gravity, at an initial temperature of 15° C., the increase of temperature should not exceed 15°, and when mixed with an equal bulk of the same acid, of 1·53 specific gravity, the oil should not impart any deeper tinge than pale yellow to the acid, either in the cold or on warming.

The Pfalz Railway.

(*a*) *Machine Oil.*—The essential particulars for mineral lubricating oils are, freedom from gum-like impurities ["schleim"], resins, acids, alkalies, salts, tar, and water, and absence of drying properties, or liability to undergo alteration after lapse of time. To these must be added a specific gravity of between 0·900 and 0·915 at 15° C., coupled with a very constant degree of consistency within the ordinary limits of temperature. The oil should not congeal at −10° C., and must remain fluid at −5° C. It must have a flashing point of 160° C., and a burning point of 180° C. Finally, when heated, frothing should not occur.

(*b*) *Cylinder Oil.*—The conditions are identical with those for class (*a*), with the following exceptions:—Flashing point 260° C., burning point 310° C. The oil must remain fluid at 5° C.

Royal State Railways of Saxony.

Mineral lubricants are employed for locomotives as well as for tender and wagon axles. If the oil offered is unsuitable for use in warm portions of the locomotive (cylinder, slide valve, &c.), this must be particularly specified in the tender form. It is essential that the oil be free from acid, tar, resin, and water, neither too thin nor too thick, according to the season, and that it should deposit no sediment on storing. Winter oil is expected to remain perfectly fluid even at −10° C. The tender should state whether the oil is of German, Russian, or American origin, and give in addition particulars of—

1. Viscosity, in degrees Engler, compared with crude rape oil at −10°, −5°, 3°, 18°, and 50° C.
2. Temperature in degrees C. at which ebullition occurs.
3. Temperature in degrees C. at which *visible* vapours are evolved.
4. Temperature in degrees C. at which inflammable vapours are evolved.
5. Burning temperature, in degrees C., of the oil.
6. Coefficient of friction as compared with crude rape oil.
7. Specific gravity of the oil at 15° C.

Royal State Railways of Wurtemberg.

The mineral lubricating oils must be free from gum-like impurities ["schleim"], resins, acids, salts, tar, paraffin residues, and water, and must possess no drying properties. It must neither alter after long storage nor deposit any sediment, and must be thoroughly suitable for the required purpose. Limits of specific gravity at 15° C. between 0·90 and 0·92, congealing point not over −10°, minimum flashing point 160° C., and burning point 185° C. The oil should not froth when heated, and should have a viscosity (Engler) at 20° C. of eighty to a hundred times that of water.

The State Railways of Alsace-Lorraine.

The conditions and methods of testing are the same as for the Prussian railways, with the subjoined variations:—

Limits of viscosity for summer oil at—

	20° C.	30° C.	40° C.	50° C.
Highest, ...	2·5	1·3	0·8	0·6
Lowest, ...	1·5	0·8	0·5	0·4

The minimum degree of viscosity for winter oil is fixed at 1·5 at 20° C., all these being determined by Engler's viscometer, taking rape oil, of fifteen times the viscosity of distilled water at 20° C., as the standard. Flashing point above 140° C. (Pensky-Martens test). Congealing point—summer oil must remain fluid at 0° C., and winter oil at −10° C., when tested in the manner prescribed by the Prussian railways.

PETROLEUM RESIDUUM.

The rules of the New York Produce Exchange provide that "Residuum shall be understood to be the refuse from the distillation of crude petroleum, free from coke and water, and from any foreign impurities, and of gravity from 16° to 21° Beaumé."

The proportion of *coke* may be determined by diluting a weighed quantity of the residuum with petroleum spirit, passing the mixture through a filter of fine muslin, and washing, drying, and weighing the solid matter thus separated. If there is reason to suspect the presence of earthy matter, contained in the crude petroleum from which the residuum was obtained, the proportion of carbon should be determined by ignition.

The amount of *water* present, may be ascertained in the manner described in connection with the testing of crude petroleum. The author finds it convenient to employ, for the separation of the water, a tube about 6 inches in length and about half an inch in diameter, graduated from the bottom in tenths of a cubic centimetre up to 10 c.c., and surmounted by a glass-stoppered spherical bulb about 4 inches in diameter. 250 grammes of the oil is taken for the test, and this is diluted to any required extent with petroleum spirit or kerosene of low specific gravity. The bulbed tube is placed in a water bath maintained at a temperature of about 150° F., until the whole of the water has separated and forms a distinct stratum beneath the oil in the graduated tube. The quantity of water is then noted at 40° F., each cubic centimetre representing 0·4 per cent.

PARAFFIN TESTING.

The testing of solid paraffin comprises the determination of the melting point, the percentage of oil and the percentage of water and dirt. The various methods of testing in common use have been somewhat fully treated in papers by D. A. Sutherland,[1] J. Stuart Thomson,[2] and the author.[3]

Melting Point.—The "melting point" is understood commercially to be the temperature at which the liquified paraffin commences to solidify. In conducting the "*English test*," the paraffin is melted in a test tube about three-quarters of an inch wide, and is then stirred with a thermometer while the tube is held in the air, until a point is reached at which the crystallisation liberates sufficient heat to arrest the cooling and keep the mercurial column in the thermometer stationary for a time. This test resembles Dalican's method of determining the solidifying point of fatty acids.[1] In Saybolt's apparatus for applying the test to a number of samples simultaneously, the melted paraffin is contained in a series of parallel troughs resting on a carriage which travels backwards and forwards. The thermometers are held stationary in a frame, with their bulbs just immersed.

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[1] *Journ. Soc. Chem. Ind.*, 1887, 123 and 271.

[2] *Ibid.*, 1891, 342.

[3] *Ibid.*, 1884, 430; 1887, 125; and Cantor Lectures at the Society of Arts, 1886.

In carrying out the "*American test*," a hemispherical cup, 3¾ inches in diameter, is three-fourths filled with the melted paraffin, which is then allowed to cool spontaneously until a very thin film extends from the sides of the vessel to a thermometer with a round bulb half an inch in diameter, suspended so that the bulb is three-fourths immersed, in the centre of the dish. The American test usually indicates a "melting point" from 2½° to 3° F. higher than the English test.

Capillary Tube Method.—Another method of determining the "melting point," consists in noting the temperature of solidification of a minute quantity of the sample previously fused into a capillary tube, care being taken not to overheat it during fusion. The capillary tube is allowed to cool slowly by the side of a thermometer in a beaker of water.

Tagliabue's Paraffin Tester.—An instrument sold by Charles J. Tagliabue, of New York, for determining the melting point of paraffin, consists of a metal funnel, with a water-jacket in communication with a heating vessel. The test is made in the following manner:—The heating vessel is nearly filled with water, and closed with a cork which carries a thermometer. A lighted spirit lamp is then placed beneath it, and the temperature of the water (which circulates through the jacket of the funnel) is raised to, and maintained at, a point about 15° or 20° F. above the anticipated melting point of the sample to be tested. Another thermometer having been fixed in the funnel so that its bulb occupies the apex, "about a spoonful" of the sample, finely broken up, is put into the funnel. As the paraffin melts and drops from the bulb of the thermometer, it is carefully watched, and as soon as it is perfectly transparent, the temperature indicated by the thermometer is recorded as the melting point of the sample.

Estimation of Oil.—The determination of *oil* is made by pressing the paraffin and noting the loss in weight, but as the results vary according to the temperature adopted, the amount and *duration* of the pressure, and the quantity of material in relation to the surface subjected to pressure, the test is a purely arbitrary one. Moreover, there is no natural line of demarcation between the solid and liquid hydrocarbons present. In averaging the sample and preparing it for testing, it will be found convenient to pass it through a small mincing machine.

Lever Presses.—Fig. 258 represents a press employed some years ago in the laboratory of the author. It has a steel crosshead, the deflection of which is magnified by levers so as to indicate the pressure. Fig. 259 shows the press which the author now uses. In this, the pressure is regulated by a heavily weighted lever. Each press has a circular press cup and a plunger 5⅝ inches in diameter, and in testing American paraffin scale, a pressure of 9 tons on the total surface is used. The pressure is applied for five minutes at a temperature of 60° F. to 500 grains of the scale placed between circular pieces of calico cut with a steel punch to fit the cup. The expressed oil is absorbed by a number of discs of blotting-paper placed above and below the cloths containing the cake. The paraffin is brought to the

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[1] See *Journ. Soc. Chem. Ind.*, viii., 1889, 424.

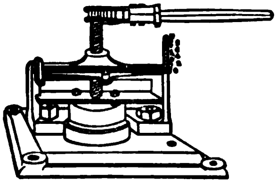

Fig. 258.

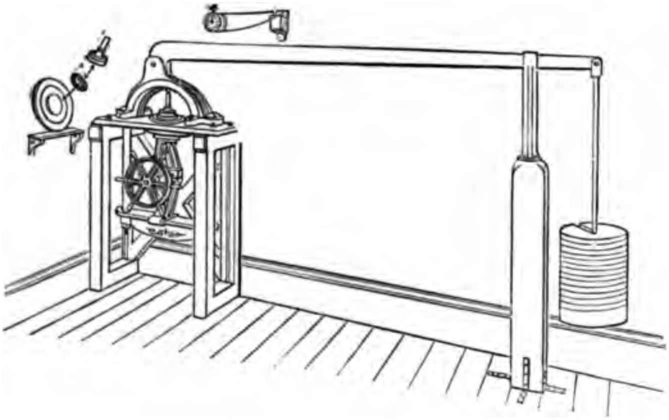

Fig. 259.

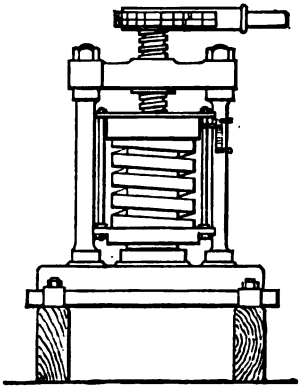

Fig. 260.

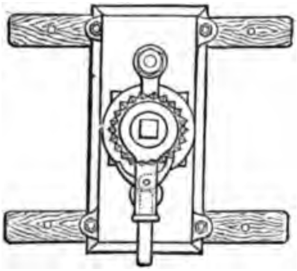

Fig. 261.

standard temperature before treatment, and thermometers inserted in mercury cups indicate the temperature of the press cup and plunger. The plunger and cup are detachable from the bed plate, &c., so that they may be cooled in water at 60° F.

Figs. 260 and 261 illustrate a press designed by Mr. McCutchon. This is provided with a helical spring, the extent of compression of which indicates the pressure applied.

Hydraulic Press.—A compact hydraulic press with Bourdon gauge, introduced by Messrs. Clarkson and Beckitt, for paraffin testing, is shown in Fig. 262.

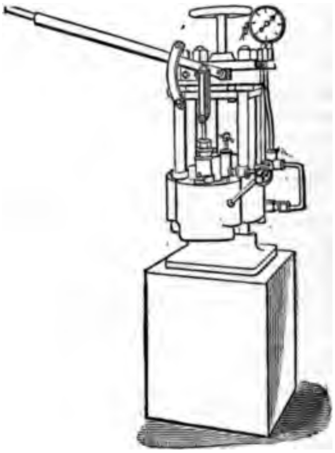

Fig. 262.

Estimation of Water.—The water may be determined in paraffin scale by heating a weighed quantity (preferably 25 grammes) in a tared evaporating dish, with constant stirring with a thermometer until the water is driven off. The loss shows the amount of water. The material should be raised to and maintained at a temperature somewhat higher than the boiling point of water. When the amount of water is large, there is some danger of loss from spurting, and the operation is also tedious. It may then be determined by distillation or subsidence, the paraffin being kept in the latter case in a molten condition until all the water has separated. A convenient apparatus, introduced by Sutherland, for the subsidence test, consists of a bulbed tube, the upper, pear-shaped portion of which is 2½ inches wide and 9¼ inches long, and the lower, tubular portion three-eighths of an inch in diameter and graduated in tenths of a cubic centimetre, or in grains. In performing the test, 64 grammes (1,000 grains) is placed in the tube, which is immersed in water at 150° F. until the scale has melted and the water has subsided, the vessel being tapped to facilitate the separation. The lower part of the tube is then plunged into cold water, so that a film of paraffin solidifies over the separated water. As much as possible of the paraffin having been poured off, the remainder is removed by agitation with warm, "hydrated" petroleum spirit. The water is read off at 60° F. Another method of estimating the water when the amount is large, consists in treating the scale with petroleum spirit, already containing as much water as it will take up, and measuring the water thus separated. A method of estimating water by distillation is described on the next page.

Estimation of Dirt.—The dirt is estimated with the water in the above tests, but when the quantity present is considerable, it is collected on a filter paper, washed with mineral spirit, dried and weighed. In Scotch scale, the dirt rarely exceeds 0·2 per cent., and consists chiefly of vegetable fibre from the cloths used in pressing, and of iron oxide from the condenser worms.

Scottish Methods.—The following methods of testing Scotch paraffin scale and heavy mineral oils, have recently been decided upon by the chief chemists of the companies constituting the Scottish Mineral Oil Association, Price's Patent Candle Company, and the author. They have been discussed in detail by Mr. J. Stuart Thomson in the paper already referred to :—

I. Scale Analysis.

1. *Sampling of Hard Scale.*—The sample is to be taken by means of a metal tube, which is made slightly conical; the small end is inserted in the scale, and by means of a handle, which is removable, it is forced through the scale to be sampled. By this means, a cylindrical core of paraffin is obtained.

Care must be taken to see that the tube is of such a length that the sample will represent the whole length or depth of the cask, waggon, or bing.

2. *Preservation of Samples of Scale.*—Immediately after the sample has been drawn, it is to be thoroughly mixed, placed in suitable wide-mouthed bottles, which may be closed either with glass stoppers or good corks; if the latter are used, they should be covered with paraffin paper, or soaked in melted paraffin wax, before being inserted. The bottles are then finally sealed in the usual manner. The scale should be tightly packed into the bottles, which should be completely filled.

3. *Determination of Oil in Scale.* (*a*) *Press to be used.*—While no one special form of press is recommended for general adoption, the press used must have some arrangement for indicating the pressure applied. The cup in which the scale is placed during the application of pressure to have an area of 20 square inches.

(*b*) *Preparation of the Sample.*—A quantity of the scale, after having been freed from water and dirt by melting and subsidence, is to be allowed to cool over night to a temperature of 60° F. The solid mass is then ground to a fine powder, a portion of which is used in the determination of the oil.

(*c*) *Quantity of Scale to be used.*—The quantity of scale to be used in the determination of oil is to be 250 grains, which quantity may, however, be reduced to 150 grains in the event of the scale containing much oil (over 7 per cent.). With "soft" scale the smaller quantity should be taken.

(*d*) *Temperature at which the Scale is to be Pressed.*—The temperature of the scale and the press is to be 60° F.

(*e*) *Time which the Scale is to remain under Pressure.*—The scale is to remain under pressure for fifteen minutes.

(*f*) *Pressing Cloths and Papers.*—Fine linen pressing cloths and a number of layers of filter paper, sufficient to absorb all the oil, to be used. The exterior papers must not be soiled by oil.

(*g*) *Pressure to be applied.*—The maximum pressure is to be 10 cwts. per square inch, and the working pressure 9 cwts. per square inch.

4. *Determination of Water in Scale.*—The amount of water present in scale may be determined by either of the following processes :—

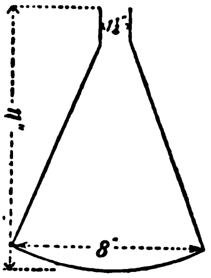

Fig. 263.

(*a*) *Distillation from a Copper Flask.*—From 1 to 2 lbs. of the scale are heated in a conical copper flask of about the dimensions shown in Fig. 263; this is connected to an ordinary Liebig condenser. By means of a powerful Bunsen burner or lamp, the water, accompanied by a small quantity of light oil, is volatilised and condensed. The distillate is received in a narrow graduated measure, so that the volume of water can be readily ascertained. As a little water usually adheres to the sides of the condenser tube, this is to be washed out with hydrated gasoline or naphtha, and added to the principal quantity.

(*b*) *Price's Company's Method.*—500 grains of the scale to be tested are weighed in a tared porcelain basin, and heated with constant stirring to 230° F., until bubbles cease to be given off; the loss is then determined.

500 grains of the same scale, which has been freed of its water and dirt by melting at a gentle heat and subsidence, are to be heated in the same way, to a similar temperature, for the same time, and the loss again determined. The loss in the second instance is now to be deducted from the loss found in the first experiment, and the remainder is then to be taken as the quantity of water present.

5. *Determination of Dirt in Scale.*—The amount of dirt present in scale is to be determined by melting a weighed quantity of the scale, and, after subsidence, pouring off the clear paraffin. The residue is then mixed with naphtha, thrown on a weighed dry filter paper, washed with naphtha or gasoline, dried, and weighed. When available, the quantity of scale to be used in the determination of the percentage of dirt should not be less than 7,000 grains.

6. *Calculation of the Results of the Analysis of Scale.*—As the oil is determined on scale which has been freed from water and dirt, the result must be calculated back to the original scale containing water and dirt.

7. *Determination of the Melting (Setting) Point of Solid Paraffin.*—This is to be determined by what is known as the "English" test—*i.e.*, a test tube about 1 inch in diameter is filled to the depth of about 2 inches with the melted paraffin, a small thermometer is inserted, and the whole steadily stirred, while the test tube and its contents are allowed to cool slowly. The temperature at which the thermometer remains stationary for a short time is the melting (setting) point.

II. Flashing Point of Heavy Mineral Oil.

8. *Determination of the Flashing Point of Heavy Mineral Oil.*—The oil cup and cover of the ordinary "Abel" flash-point apparatus is to be employed. The cup is filled with oil in the usual manner, and the rate of heating is to be such that at least fifteen minutes are taken in raising the temperature of the oil to 300° F. In the event, however, of a dispute arising as to the correct flashing point of a heavy mineral oil, the question is to be decided by means of the "Pensky-Martens" apparatus (*Journ. S. C. Ind.*, viii., 734).

III. Viscosity of Mineral Oil.

9. *Determination of the Viscosity of Mineral Oil.*—The instrument known as the "Redwood" viscometer is that which is to be employed in the determination of the viscosity of mineral oils. The instrument is to be standardised according to the directions given by Mr. Boverton Redwood (*Journ. S. C. Ind.*, v., 127). Ordinary results are to be expressed as the time in seconds which 50 c.c. of the oil take to flow through the orifice, at a temperature of 70° F.

IV. Setting Point of Mineral Oil.

10. *Determination of the Setting Point of Mineral Oil.*—This is determined in the following manner:—Into a test tube having a diameter of about 1¼ inch, the oil to be tested is added to the depth of about 2 inches; the tube is then immersed in a freezing mixture, the oil being slowly stirred with a thermometer till it is cooled down considerably below the temperature at which solid paraffin first appears. The tube is then removed from the freezing mixture, the oil constantly stirred with the thermometer, and the point carefully watched at which the last trace of solid paraffin disappears. This operation is repeated with the same sample of oil until two experiments give concordant results, the temperature so found being the setting point.

Chemical Examination.—The chemical examination of the raw materials and products to which this work relates, as distinguished from the application of the usual physical tests already described, is not, as a rule, necessary, and its character varies with the use which is to be made of the material. The principal chemical tests have been fully described in Mr. Alfred H. Allen's *Commercial Organic Analysis*, 2nd ed., ii., and from this work, the portion of which relating to petroleum was submitted by Mr. Allen to the author for perusal and revision, a considerable amount of the following matter is taken.

It has been already shown in the section dealing with the Chemistry of Petroleum, &c., and in that treating of the Shale Oil Industry, that the petroleum of America consists mainly of members of the paraffin group; Russian petroleum of naphthenes, which are isomeric with the olefines; and shale oil, very largely of hydrocarbons of the olefine group. The action of concentrated nitric and sulphuric acids on shale oil is much more energetic than on petroleum, and may serve to distinguish these products, but a better method consists in the treatment with bromine, which has no action on the paraffins or naphthenes, but is readily absorbed by olefines. The following method of applying the **bromine test** to commercial products from shale and petroleum, is recommended by Mr. Allen:—An approximately decinormal solution of bromine is made by dissolving 2 c.c. of bromine in 750 c.c. of recently distilled carbon bisulphide, and the solution having been dried by adding some lumps of fused calcium chloride, is preserved in the dark. From 0·3 to 1 gramme of the oil, or a certain volume of a solution of the oil in carbon bisulphide containing a known amount of the oil, is weighed or measured out into a perfectly dry stoppered flask or separator, and the solution is diluted, if necessary, with carbon bisulphide (dried over calcium chloride) to about 25 c.c. Then 25 c.c. of the bromide solution is added and the flask is stoppered, agitated, and left in the dark for a quarter of an hour. If the liquid is not distinctly red after the agitation, a further quantity of the bromine solution is added without delay. After a quarter of an hour, an excess of an aqueous solution of potassium iodide is poured in, and the mixture is agitated. The bromine which was not absorbed by the oil, having thus been replaced by an equivalent amount of free iodine, the flask is removed to a light place and the contents titrated with a decinormal solution of sodium thiosulphate, made by dissolving 24·8 grammes of the crystallised salt in one litre of water. The titration is conducted in the usual manner, the final change being rendered more sharp by adding a few drops of starch solution when the bisulphide is nearly decolourised. The bromine solution used, requires to be occasionally standardised by treating 25 c.c. of its solution in carbon bisulphide with potassium iodide and titrating exactly as above. The difference between the volume of thiosulphate now required and that used after treating the oil, represents the volume corresponding with the amount of bromine absorbed. One c.c. of the thiosulphate solution should correspond with 0·008 gramme of bromine. If the crystalline thiosulphate used be pure, and be crushed and dried between blotting-paper before being weighed out, the solution will contain so nearly the right proportion of the salt that, if it be required for ordinary use, there is no necessity to standardise it by iodine. It is found that, if the bromine treatment of the oil be allowed to proceed in the light (even if diffused), a markedly larger quantity of bromine is absorbed. The following table gives the results obtained by Mr. Allen in the application of this system of testing to a number of oils :—

Description of Substance.	Sp. gr. at 60° F. (= 15·5° C.)	Grammes of Bromine reacting with 100 grammes of Sample.	Bromine as HBr per 100 grammes of Sample.
Gasolines—			
From shale,	0·665	62·2	1·1
From American petroleum,	0·650	17·9	3·1
Naphthas—			
Shale naphtha,	0·720	67·2	4·0
C-naphtha from American petroleum,	0·706	18·3	...
Burning oils—			
From shale,	0·813	51·3	3·0
From American petroleum,	0·800	34·8	...
From Russian petroleum,	0·821	2·0	0·1
Intermediate oils—			
From shale,	0·850	48·2	...
"Mineral sperm oil" (American petroleum),	0·847	32·3	...
"Pyronaphtha" (Russian petroleum),	0·868	1·9	0·1
Lubricating oils—			
From shale,	0·890	25·6	5·8
Cylinder oil (from shale),	0·890	11·0	...
From American petroleum (heavy spindle oil),	0·900	11·7	...
From Russian petroleum,	0·904	4·9	0·8
"Champion oil" (American petroleum),	0·911	9·9	0·8
Cylinder oil (Russian petroleum),	0·909	5·8	0·6
Vaselines—			
From American petroleum (Chesebrough Co.),	0·856	11·3	1·8
From Russian petroleum,	...	1·7	0·3
Paraffin waxes—			
From shale (m.p. 52° C.),	...	1·7	0·5
From petroleum (m.p. 54° C.),	...	0·9	0·2

MM. A. Riche and G. Halphen[1] have recently devised a process for determining whether a petroleum distillate, such as kerosene, has been obtained from American or from Russian crude petroleum, and for distinguishing crude petroleum from mixtures of petroleum distillate and residuum. The process consists in the gradual addition by means of a burette, of a mixture of equal volumes of anhydrous chloroform and 93 per cent. alcohol, to 4 grammes of the sample of oil, until solution is effected and the liquid becomes clear. In the case of the petroleum distillates, it was found, as the result of a large number of experiments, that while with the more volatile fractions obtained respectively from American and Russian crude petroleum, there was but little difference in solubility, with the fractions of higher boiling points, having densities of 0·800 and upwards, the American product required a considerably larger quantity of the solvent to produce a clear liquid than sufficed for the Russian product of corresponding specific gravity. As regards the other application of the process it was found that samples of crude petroleum required much more of the solvent to produce a clear liquid, than fractions of the same density obtained by distillation.

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[1] *Journ. Pharm. Chim.*, 1894, xxx., 289; *Journ. Soc. Chem. Ind.*, xiv. (1895), 190.

The author has found this process useful in the approximate determination of the proportions of American and Russian kerosene present in mixtures of these two products. 25 per cent., or less, of Russian kerosene, in admixture with American kerosene, may be detected, but it is necessary to pay particular attention to the strength of the alcohol used in preparing the solvent liquid, very slight differences in the amount of water having a marked effect upon the results. A number of blank experiments should, therefore, be performed with oils of known origin and mixtures in various proportions, with the freshly-prepared test liquid, before using it in the examination of unknown samples. The following results were obtained in the author's laboratory :—

	c.c. of solvent required for 4 grammes.	
	Actual.	Theoretical.
A. American kerosene, specific gravity 0·797, . .	6·1	...
B. Russian kerosene, ,, 0·824, . .	4·8	...
25 per cent. A, and 75 per cent. B, ...	5·1	5·2
50 ,, ,, 50 ,, ,, ...	5·5	5·5
75 ,, ,, 25 ,, ,, ...	5·8	5·8

For determining the **ash** yielded by petroleum, it is usual to evaporate down a known volume of the oil and ignite and weigh the residue. It is best to distil down 1,000 grammes of the oil to about 40 grammes, and to transfer this to a weighed platinum dish, evaporate to dryness, ignite, and weigh. A. Stepanow[1] recommends the following method as avoiding the unpleasant production of soot which otherwise takes place, the bulk of the oil being evaporated off prior to the ignition proper, but the whole test being performed in the weighed dish :— 70 to 90 grammes of oil is heated in a platinum dish, over which is placed a closely-fitting conical or globular glass cover connected to a condenser, a receiver, and finally a powerful aspirator, by means of tubing. In about fifteen minutes, the greater part of the oil will have been evaporated and collected in the receiver. A fresh portion is then poured into the dish, and so on, until 200 to 300 grammes has been treated. The comparatively small residue of coke remaining in the dish may then be heated until no more fumes are evolved, and finally ignited over a blowpipe or in a current of oxygen.

A mineral lubricating oil should volatilise without the production of any very pungent odour, and if the vapour is ignited and the flame extinguished, there should be no smell of resin or acroleïn. On ignition, the oil should leave no inorganic residue, or only a trace (less than 0·05 per cent.). If a residue is left, the oil may contain alkali, or the soap of an alkali metal, or palmitate or oleate of aluminium. The presence of the last two may be detected by agitating the oil with ether and dilute acid, separating the aqueous layer and adding to it a slight excess of ammonia, when a white gelatinous precipitate will be thrown down if either of the aluminium compounds in question is present.

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[1] *Chem. Zeit. Rep.*, 1892, xxxi., 348.

The following particulars of the "**alkali test**" for Russian petroleum products, which has already been briefly described on p. 542, have been given by K. Lissenko and A. Stepanow.[1]

About ten years ago, endeavours were made in the Russian petroleum districts to reduce the quantity of caustic soda used in the refining of petroleum. Kerosene was obtained which satisfied the usual tests, but in practice was found unsuitable for use as lamp oil, as it did not rise freely in the wick. Investigation proved that this was due to the presence, in the kerosene, of small quantities of saponaceous salts, and analysis sometimes showed as much as 0·04 gramme of ash from 1,000 grammes of kerosene, this ash consisting of CaO, MgO, Fe_2O_3, Na_2O, and SO_3. Further investigation proved that for a lamp oil, the ash should certainly not exceed 0·01 gramme per 1,000 grammes of oil, and that in the best oils, it generally varied between 0·004 and 0·007 gramme. The presence of these soaps or salts is equally detrimental in lubricating oils.

As the ash determination is troublesome, and somewhat uncertain on account of possible loss of sodium salts by volatilisation, the so-called "alkali test" was introduced. Though used with various slight modifications, it consists mainly in mixing, in a flask, 300 or 500 c.c. of kerosene with 6 or 10 c.c. of a 2 per cent. solution of caustic soda, warming to 60° or 70° C., and shaking the whole violently for five minutes. The mixture is then transferred to a separating funnel, the alkaline extract filtered through a double filter, and acidulated with HCl. The acids in the petroleum and in the saponaceous salts which are extracted by the alkali, are thus precipitated, and the degree of turbidity produced thereby, indicates the amount of impurity present in the oil. The turbidity—originally simply roughly stated as satisfactory or the reverse—is now estimated by the size of print which can be read through the opalescent liquid contained in a glass cylinder of given diameter, the operator being required to specify the diameter of the cylinder, and the size of print he can just discern. The kerosenes are now divided into classes according to the results given by this "alkali test," and a definitely fixed scale is being constructed. Even the best kerosenes give a slight opalescence. The theory of the test is clear—viz., that the soaps and acids present in the oil are dissolved in the dilute alkali, and on acidifying the alkaline extract, the acids which are insoluble in water, render the extract opalescent. In testing lubricating oils, which generally contain a considerably larger quantity of ash (sometimes as much as 0·125 gramme per 1,000 grammes of oil) the test is somewhat modified. In this case, 5 c.c. of a 1·5 per cent. caustic soda solution, is mixed with 10 c.c. of the oil, the whole heated to 80° C., shaken violently for some time, allowed to stand at 70° C. for two to three hours to settle, and then examined. If the aqueous layer is then milky, and there is a more or less considerable precipitate between the aqueous and the oil layers, the oil is undoubtedly insufficiently purified. In most cases, the aqueous solution is clear, but a more or less marked yellowish-red film is seen at the point of contact of the two layers. In such cases, if the ash is small, the oil is a satisfactory lubricating oil. It only very rarely occurs that the oil is so absolutely free from salts and acids as to give no film. Another form of this test sometimes used for kerosene, is to shake the oil to be tested, with a small quantity of strong caustic soda solution. If the kerosene is pure, the two liquids rapidly separate again with a perfectly bright contact surface. If the kerosene is impure, a whitish film forms at the point of contact of the two liquids. This form of test, however, only decides between pure and impure oil, and gives no indication of the degree of impurity.

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[1] *Dingler's polyt. Journ.*, ccxc., 139-143; *Journ. Soc. Chem. Ind.*, xiii. (1894), 177, 178.

The view held in Baku and elsewhere of this alkali test, was that the alkali dissolved out the soaps (possibly in the form of basic salts), and that the test was a definite proof of the presence or absence of these soaps in the oil. Lissenko and Stepanow have carefully investigated this matter, and their conclusions (confirmatory, in many respects, of the work of Doroschenko and of Engler) are as follows:—These saponaceous salts are almost absolutely insoluble in pure neutral petroleum, but dissolve readily in the same if it contains a trace of naphtha acids. Almost all petroleum contains more or less of these acids, which are generally mixtures of hydro-aromatic and sulphonic acids and phenolic compounds. Kerosene, when distilled in the air, or even when shaken at 70° to 80° C. with air, usually undergoes slight oxidation with formation of traces of these acid compounds, so that absolutely neutral kerosene is rarely met with. The salts of these naphtha acids undergo partial hydrolysis in the presence of water, and though excess of alkali in some degree prevents this hydrolysis, the latter is not completely stopped till the excess of caustic soda amounts to at least 10 per cent. of the water. Thus, in the purification of petroleum by weak alkali, as now often practised, and subsequent washing with water, part of the salts first formed becomes again hydrolysed, the acid so liberated is taken up again by the petroleum, and the acid petroleum in its turn redissolves some of the salts. Lissenko and Stepanow, therefore, believe that for good purification, final treatment with strong caustic alkali should be adopted. The presence of small quantities of these naphtha acids in the oil does not seem to be detrimental so long as no salts are present. From this point of view the alkali test, as at present carried out, is unsatisfactory, as it really only determines the presence or absence of these naphtha acids without deciding whether they are present in the free state alone, or also in the form of the detrimental salts. As the ash determination is difficult, and not altogether satisfactory, testing for these salts is at present unsatisfactory. The authors suggest as a test which, as far as preliminary trials go, seems to be satisfactory—the shaking of the petroleum to be tested with water containing a few drops of phenolphthalein. If salts are present, hydrolysis takes place, and the liberated alkali, being taken up by the water (whilst the acid remains in the oil), colours the solution violet. The aqueous extract may even be titrated. Further investigation of this test is, however, required.

As a test for the presence of **sulphur compounds** in *mineral spirit*, the sample may be boiled for a few minutes with alcohol and a few drops of ammonia, and nitrate of silver solution then added, when there should be no brown coloration. Mineral spirit containing sulphur compounds is unfit for use as a substitute for oil of turpentine, as it is liable to cause darkening of light coloured paints. Warm water agitated with mineral spirit should not acquire the faintest acidity, and should give no precipitate with barium chloride. *Mineral burning oils* may contain sulphur compounds originally present in the raw materials from which they were obtained. Oils which, like those produced by the process of "cracking," consist largely of olefines, are also liable to contain sulphonates resulting from the action on the hydrocarbons of the sulphuric acid used in the process of refining.

There are several methods in use for the detection and estimation of sulphur. The "litharge test" in use in Canada, has already been referred to on p. 541. A simple qualitative test consists in heating the oil with a fragment of metallic sodium to the boiling point for some time, in a flask provided with an inverted condenser. After cooling, water is added drop by drop until the sodium has been dissolved. More water is then added; the water is separated and a drop of sodium nitroprusside is added. A fine violet-blue colour is produced if the petroleum contains sulphur. This test only operates with sulphur compounds which form sodium sulphide with sodium, and thus discriminates between such sulphur compounds and sulphuric acid. The sodium nitroprusside is prepared by warming a few crystals of potassium ferricyanide with strong nitric acid until red fumes are copiously evolved, the solution being then diluted and neutralised with sodium carbonate. Carius converts the sulphur into sulphuric acid by heating the oil with nitric acid, the sulphuric acid being finally precipitated with barium chloride, but the action of the nitric acid, especially in the case of shale oils, often fails to result in the complete oxidation of the sulphur. Many chemists estimate the sulphur by an ordinary "combustion" with oxygen. Höland[1] employs for the combustion process, an intimate mixture of finely-divided pure barium carbonate and potassium chlorate. A potash-glass combustion tube 40 cm. long is used, sealed at one end. The liquid to be examined is dropped in from a weighed pipette, &c., and spread about over as large a surface of this mixture as possible, conveniently by diluting with ether, and subsequently allowing this solvent to evaporate. After the combustion is over, the contents of the tube are treated with hydrochloric acid and the undissolved barium sulphate weighed. Evolution of sulphuretted hydrogen indicates imperfect oxidation. With volatile oils, or petroleum containing the more volatile hydrocarbons, the process of combustion in a current of oxygen, or that of treatment with an oxidising mixture, does not answer well, as explosions are liable to occur. In such cases, the author prefers to estimate the sulphur by burning a weighed quantity of the oil in a lamp, and passing the products of combustion through a cylinder containing glass beads moistened with ammonia, such as is employed in determining the sulphur in coal gas. The sulphur is precipitated and weighed as barium sulphate. Heavy or viscous oils which would not burn alone, must be diluted with kerosene known to contain no sulphur. The author has found as much as 119 grains of sulphur per gallon in Canadian kerosene. The products of combustion of this oil injured the plants in a conservatory.

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[1] *Chem. Zeit.*, xvii., 99 and 130.

The following modification of the Burton-Sauer method, is described by C. F. Mabery[1] as being of service in the estimation of the sulphur present in Canada and Ohio petroleums:—The substance contained in a porcelain boat, is burnt in a current of air, the products of combustion passing through a dilute solution of caustic soda. The combustion tube (18 mm. internal diameter) is constricted at the middle, and the air passes in from the rear through a narrow tube which reaches this constriction. The forward part of the combustion tube is connected with a U-tube (34 cm. high, 25 mm. internal diameter) which is partially filled with broken glass, and contains 50 c.c. of caustic soda solution, of a strength corresponding to 1 mgrm. or 5 mgrms. of sulphur per cubic centimetre, according to the amount of sulphur in the oil under investigation. The titration of the excess of alkali is performed in the U-tube itself, methyl orange being used as indicator. No nitrogen acids are formed during the combustion, and the results agree closely with those obtained by the Carius method.

The sulphur present in comparatively non-volatile descriptions of petroleum, bitumen, &c., may be estimated by the magnesia-soda process. This consists in making a mixture of about 1 gramme of the substance with 1½ gramme of a mixture of 2 parts of calcined magnesia and 1 part of sodium carbonate, and igniting it in a platinum crucible for over an hour. The mass is extracted with water with the addition of bromine to ensure perfect oxidation, the solution is then filtered, acidulated with hydrochloric acid, heated to expel bromine, and the sulphuric acid, into which form the whole of the sulphur has been converted, is precipitated with barium chloride. Magnesia and sodium carbonate free from sulphur compounds must of course be used.

Mineral lubricating oils are frequently mixed with seed oils; "blown" rape oil, or "blown" cotton oil, being in some cases employed to give largely increased viscosity. A small proportion of an animal oil is often added to mineral cylinder oils. Artificial viscosity is occasionally imparted to some of the less viscous mineral lubricating oils by the addition of aluminium palmitate or oleate. Admixture with rosin oil is also sometimes practised. Fixed oils may be detected, and the proportion determined by difference, by treating the sample with an alcoholic solution of caustic potash, and separating the hydrocarbons from the soap by means of ether, which is afterwards removed by distillation and evaporation. The details of this process are given fully in Allen's work already referred to. With some descriptions of compound oils, the separation of the hydrocarbons is attended with considerable difficulty, and the author finds that in such cases the extension of the Koettstorfer process described by Mr. Harold Gripper[1] may be adopted with advantage. The process consists in the saponification of the sample with alcoholic potash solution and titration with hydrochloric acid. It is obvious that unless the nature of the saponifiable oil, and, therefore, its saponification equivalent, is known, the mean of the equivalents of oils likely to be present must be taken, and thus an error may be introduced; but even allowing for this, the author's experience is that the process gives, with some compound oils, more satisfactory results than the method previously described. Besides which the Koettstorfer process may be carried out in the course of an hour, while the other occupies a considerable amount of time.

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[1] *Amer. Chem. Journ.*, xvi., 544-551; *Journ. Soc. Chem. Ind.*, xiv. (1895), 196.

For the detection of fixed oils in mineral oils, Lux's test may be employed. This consists in heating about 5 c.c. of the oil in a test tube with a small piece of sodium hydrate, the presence of 10 per cent. or more of saponifiable oil being indicated by the solidification of the liquid on cooling. An improvement on this test, described by Mr. James Cameron,[2] consists in heating portions of the sample in two test tubes in a paraffin bath to a temperature of 200° to 210° C., some shavings of potassium being placed in one tube and a stick of potassium hydrate, standing about 1 cm. above the surface of the oil, in the other. It is stated that if the mineral oil contains as much as 2 per cent. of fatty oil, the sample is converted into a tough jelly in one of the tubes, and usually in both.

A method employed at Baku for testing the neutrality of kerosene is described on p. 542. Mr. Allen recommends that in the case of a lubricating oil, the proportion of **free acid**, which may be considerable when an animal or vegetable oil has been mixed with a mineral oil, should be determined first in the original oil, by a decinormal solution of caustic soda, using phenolphthalein as an indicator. Another portion of the oil (50 grammes), mixed with an equal bulk of water, is then heated in a closed bottle, immersed in water, and frequently agitated. After six or eight hours, the bottle is opened and the oil and water are separately titrated as above. The acidity of the water will usually be due to free sulphuric acid produced by decomposition of sulphonates in the mineral oil, and if considerable, indicates an inferior oil. The acidity of the oil itself will indicate the amount of fatty acids formed by the heating with water, together with the acids originally present. In the case of cylinder oils, the heating with water may be performed by placing the oil and water in a sealed glass tube, plunged in a boiling saturated solution of calcium chloride. The titration of the aqueous solution is effected in the usual manner, but the oil is treated by the method first proposed by Hausmann. A few drops of an alcoholic solution of phenolphthalein is added to some methylated spirit purified by re-distillation, and dilute caustic soda solution is added drop by drop until the liquid retains a faint pink colour. Having thus been freed from acid, from 50 to 100 c.c. of the spirit is poured into a stoppered flask in which a weighed quantity—say 50 grammes—of the oil has been placed, and the mixture is heated to the boiling point with frequent agitation. If the oil contain no free acid, the pink colour will be unchanged, but if the colour disappear, a semi-normal solution of caustic soda (20 grammes sodium hydrate in 1 litre of water) is added drop by drop with constant agitation, until the pink colour returns and remains after vigorous shaking. Where only slight acidity is suspected, a deci-normal alkali should be used. The acidity is determined by the amount of caustic soda required, but the amount of the acid or acid-producing bodies cannot be precisely determined unless their nature is also known. Thus, 1 c.c. of the semi-normal alkali corresponds with 0·256 gramme of free palmitic acid, but with 0·284 gramme of stearic acid.

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[1] *Chemical News*, lxv. (1892), 27.

[2] *Oils and Varnishes*, 1886, 283-284.

For the detection of **rosin oil**, Allen recommends the addition to a few drops of the sample, dissolved in about 1 c.c. of carbon bisulphide, of a solution of stannic bromide, with excess of bromine, in carbon bisulphide. The production of a fine violet colour, indicates the presence of rosin oil. This test is a more delicate modification of that of Renard, who observed that anhydrous stannic chloride produces a violet colour with rosin oil. The stannic bromide is best prepared by allowing bromine to fall drop by drop upon granulated tin contained in a flask immersed in cold water. When the permanent colour indicates the presence of excess of bromine, the product is diluted with three or four times its bulk of carbon bisulphide, in which stannic bromide is soluble. As rosin oil is more soluble than mineral oils in acetic acid, it may be partially separated, and the test rendered more delicate, by agitating the sample in the cold with two volumes of glacial acetic acid, and applying the test to the acid solution. Professor Finkener of the Experimental Institution at Charlottenburg, recommends the use of a mixture of 1 volume of chloroform and 10 volumes of alcohol of 0·818 specific gravity, for separating rosin oil from mineral oils. Ten volumes of this mixture will dissolve, at 23° C., 1 volume of rosin oil, leaving the mineral oil undissolved.

A process for the quantitative separation of rosin oil from mineral oil, has been given by Mr. P. C. M'Ilhiney.[1] It is well known that nitric acid when heated with rosin oil, converts the oil into a brittle red resin, whilst mineral oils are not much affected when similarly treated. The resin was found to be insoluble in petroleum ether, in which the mineral oil readily dissolves. The following method of carrying out the process is recommended :—

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[1] *Journ. Am. Chem. Soc.*, xvi., 385, 388; *Journ. Soc. Chem. Ind.*, xiv. (1895), 198.

50 c.c. of nitric acid (specific gravity 1·2) is heated to boiling in a flask of 700 c.c. capacity. The flame is removed, and 5 grammes of the oil is dropped in. The flask is then heated on the water bath, with frequent shaking, for fifteen to twenty minutes, and about 400 c.c. of cold water is added. The contents of the flask having become quite cold, the unchanged mineral oil is next dissolved by shaking with petroleum ether, which is separated and distilled in the usual manner. The residual oil is weighed; and as mineral oils lose about 10 per cent. when treated in this way, the weight obtained divided by 0·9 gives the amount of mineral oil in the quantity taken. A mixture of 76 per cent. mineral oil and 24 per cent. rosin oil gave, by this method, 76·8 per cent. of mineral oil.

The great difference in the solubility of mineral oils and rosin oils in acetone, has been taken advantage of by Demski and Morawski[1] and by Widerhold,[2] for detecting and roughly estimating adulteration with rosin oil. According to Widerhold, a Russian spindle oil of 0·898 specific gravity dissolved in from 40 to 41 volumes of acetone, and an oleonaphtha of 0·908 specific gravity in 70 to 71 volumes, while American spindle oils are almost insoluble. He applies the test by adding 2 c.c. of the oil to 20 c.c. of acetone in a glass cylinder graduated in tenths of a c.c. After being warmed in a water bath to 15° C., the liquid is agitated and allowed to settle, and the volume of undissolved oil is read off. The test is, however, a very rough one.

Mineral burning oils should bear agitation with an equal volume of sulphuric acid of 1·53 specific gravity without darkening of colour, and warm water which has been shaken with the oil, should not exhibit an alkaline or even a faintly acid reaction, or give any precipitate with barium chloride solution. Phenolphthalein is a more sensitive indicator than litmus, but as a test for acid, it is considered by some to be liable to give misleading results when neutral soaps are present, owing to the decomposition of these compounds. Water on being boiled with a **mineral lubricating oil** should remain bright and perfectly neutral. When the oil is agitated in a test tube with an equal volume of boiling water, and the tube placed in a water oven until complete separation has taken place, there should be no white film or layer at the junction of the two liquids. On agitation with an equal volume of sulphuric acid of 1·53 specific gravity, the oil should remain undarkened in colour, or should only acquire a yellow tint. When 10 c.c. of the sample is mixed with an equal volume of nitric acid of 1·45 specific gravity, there should be but little rise of temperature.

Vaseline should leave no residue when heated in a platinum dish, and the vapour, after ignition and extinction of the flame, should have no smell of resin or acrolein. Strong alcohol, on being agitated with the sample, in the proportion of two volumes of the former to one of the latter, and decanted, should exhibit neither an alkaline nor an acid reaction, and should not yield more than a trace of precipitate on dilution with water. On agitation with a cold mixture of sulphuric acid with one-ninth of its weight of water, no marked increase of temperature should occur, and the vaseline should not be much darkened.

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[1] *Dingler's polytech. Journ.*, cclviii., 82.

[2] *Journ. f. prak.* Chemie, 1893, clv., 394.

According to B. Lach,[1] crude **ozokerite** is best valued as follows:—100 grammes of the sample is mixed with 20 grammes of fuming sulphuric acid in a weighed dish, the mixture being heated to 170° or 180° C. and constantly stirred as long as sulphur dioxide is evolved. The loss is said to represent the petroleum and water, but Mr. Allen points out that the loss of sulphur dioxide and possible loss of sulphur trioxide are not allowed for, and thinks that a better plan would be to dilute the mixture and separate and weigh the paraffin wax. Another test, recommended by Lach, consists in treating 100 grammes with 10 grammes of the charcoal obtained in the manufacture of potassium ferrocyanide. The charcoal must have been previously dried at 140° C. A portion of the mixture, preferably 11 grammes, is then weighed into a weighed filter and extracted with benzene. The loss, or the residue obtained by evaporating the benzene, represents the wax.

The following method of examining **crude shale oil** is recommended by Mr. R. Tervet:—

A. 1,000 c.c. of crude oil is taken, and, after determination of the specific gravity, is distilled to dryness with the use of steam, the distillate being collected in a separator of large size. A cokey residue is left in the still.

B. The separator is placed in warm water to bring the distillate ("once run oil") to a temperature of about 40° C. After removing any water that may separate out, the oil is agitated for at least ten minutes with 5 per cent. by volume of sulphuric acid of 1·70 specific gravity, the temperature being kept down by standing the vessel in water at 35° C. When the mixture has settled for about half an hour, the "acid tar" will have separated and may be run off.

C. The oil from *B* is washed with 16 to 20 c.c. of soda solution (sp. gr. 1·30), and the "soda tar" removed, after settling for half an hour in warm water.

D. This *once purified oil* is then measured and its density ascertained, placed in a fresh still and re-distilled to dryness, the distillate being separated into two or more fractions—viz., naphtha (*E*), light oil (*F*), heavy oil (*G*), and still bottoms (*H*). When the density of the first fraction (which is not obtained at this stage from all crude oils) reaches 0·780, another receiver is substituted, and this serves until a drop, collected from the still neck on a cool spatula, shows a tendency to solidify, when the second receiver is replaced by a third. When the distillation of the third fraction is drawing to a close, a thick brown or yellow viscid fluid containing chrysene sometimes comes over and is collected separately (*H*), as, if mixed with *G* it would interfere with the crystallisation of the paraffin scale, and prevent the expression of oil from the scale. It is advisable to mix *H* and *F* together for treatment as below (*I*).

I. The crude light oil (*F*) is mixed with 2 per cent. of strong sulphuric acid, the acid tar allowed to settle without warming, and after removal, the oil is washed with an excess of soda solution of 1·36 specific gravity and the alkaline solution drawn off. This removes the chrysene existing in *H*.

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[1] *Chem. Zeit.*, ix., 905.

J. The washed oil from *I* is measured and its density taken, and is then re-distilled to dryness. The distillate is fractionated into three parts as before—viz., naphtha (up to 0·750) (*K*), light oil (*M*), and heavy oil (*N*), the latter being mixed with *G*.

K. The naphtha is added to the corresponding fraction from the former stage (*E*), and the mixture is measured and its density observed, or, if only in small quantity, it is mixed with the light oil (*M*).

O. The light oil ("crude burning oil") (*M*) obtained by re-distilling *K* is, after addition of fractions *U V*, if any, resulting from the re-distillation of the heavy oil, washed with 2 per cent. of acid of specific gravity 1·845 (without any application of heat for the separation of the "acid tar"), and agitated with dilute soda solution of specific gravity 1·020, in excess. Its volume and density are noted as the yield of *finished burning oil* (*P*).

Q. The crude heavy oil (*G*), to which is added the heavy fraction (*N*) from the second distillation of the light oil, is poured out into a shallow flat-bottomed vessel and cooled very gradually, so as to allow the paraffin crystals to properly develop, after which it is further cooled down to about - 12° C. The solid cake, wrapped in a linen cloth, of close texture, soaked in oil, is subjected to a light pressure to squeeze out the greater part of the oil, and finally to an increased pressure to remove the remainder, after which the paraffin scale (*R*) is taken out of the cloth and weighed.

S. The "blue oil" expressed from the paraffin scale, is washed with 3 per cent. of strong acid and afterwards with an excess of soda solution (sp. gr. 1·33), measured, and distilled to dryness, the distillate being divided into three fractions —viz., burning oil (*U*), intermediate oil (*V*), and unfinished lubricating oil (*W*), the first being mixed with *M*.

V. This intermediate oil is either mixed with *O* or, if considered advisable, is refined by washing with 2¼ per cent. of concentrated sulphuric acid, and subsequently with weak soda solution (sp. gr. 1·020) in excess, and estimated as *finished intermediate oil*. Its density is about 0·850.

W. The "unfinished lubricating oil" is refined in the same way by washing with 3 per cent. of acid, specific gravity 1·845, and excess of soda solution (sp. gr. 1·020). The volume and density are recorded as those of *finished lubricating oil*.

The quantities mentioned in all these processes are volumetric, and the paraffin scale is recorded in the same manner by calculation from the weight. At each stage, the specific gravity and volume of the products should be recorded.

This method of examination, suitably modified, may be adopted with samples of crude petroleum or petroleum residuum. Zaloziecki's method of estimating the **solid hydrocarbons** contained in petroleum, brown-coal oil and other oils, may be described as follows :—The more volatile constituents of the petroleum, &c., are driven off by distillation carried to a temperature of 200° C., and a weighed portion of the residue is mixed with 10 parts by weight of amyl alcohol and 10 parts of 75 per cent. ethyl alcohol. The mixture is cooled for twelve hours at 0° C., and is then filtered cold and washed, first with a mixture of amyl and ethyl alcohols and finally with ethyl alcohol alone. The separated solid paraffin is transferred to a small porcelain evaporating dish and dried at 110° C. It is then heated with concentrated sulphuric acid, to 150° to 160° C., for fifteen to thirty minutes, with constant stirring, and the acid having been neutralised, the paraffin is extracted with petroleum ether. After evaporation of the solvent, the paraffin is dried at 100° C., and weighed. In a paper dealing particularly with the examination of brown-coal tar, Mr. R. Höland[1] has given the following *résumé* of the methods of estimating solid hydrocarbons in oils :—

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[1] *Chem. Zeit.*, xvii. (1893), 1473 and 1483; *Journ. Soc. Chem. Ind.*, xiii (1894), 286.

The paraffin is the most valuable constituent of this substance, and the various oils obtained on distilling it are cooled and pressed most carefully, to extract every possible trace of solid matter. The first pressing takes place at the temperature of spring water—yielding hard paraffin, the second and third are conducted at the ordinary winter temperature, and at an artificially lowered one respectively—yielding softer products; and all the resulting press cakes and oils have to be tested to determine their commercial value.

The oldest process for this estimation is Grotowsky's, modified by Engler and Böhm, and consists in dissolving the oil in the smallest possible amount of ether in the cold and precipitating the paraffins by means of absolute ethyl alcohol. The precipitate is filtered off, washed, and more alcohol added repeatedly until oil begins to be thrown out, and the precipitates must be re-dissolved and precipitated to free them from oil. Experiments indicate that this process is not sufficiently exact, the paraffins still containing oil and *vice versâ*, besides occupying too much time. Pawlewski and Filemonowiez working on petroleum and ozokerite products, precipitate the paraffins from their solutions by adding ten to twenty times their volume of glacial acetic acid, washing the precipitate finally with ethyl alcohol of 75° Tr. This process is useless for brown-coal tar, as the softer paraffins are somewhat soluble in the liquid. Zaloziecki dissolves the oil to be tested, in five times its quantity of amyl alcohol and precipitates the paraffins by the addition of the same amount of ethyl alcohol of 75° Tr., keeping the mixture for several hours at a temperature not exceeding 4° C. with occasional agitation, filtering off the precipitate through cold dry paper, and washing with a well-cooled mixture of 2 parts of amyl alcohol and 1 of ethyl alcohol. He then dissolves the paraffins in ether, evaporates the solvent and dries the residue at 125° C. For oils containing little paraffin, he uses ten times the amount of the alcohol mixture, and allows it to stand ten to twelve hours. Modified somewhat to suit the brown-coal tar products, this process has only the disadvantage attending the use of such a high temperature for drying, besides the unpleasantness of the operation.

While ethyl alcohol of not more than 98 per cent. strength only yields turbid solutions with brown-coal tar oils, 99·5 to 100 per cent. alcohol dissolves these oils, when free from paraffin, up to the specific gravity 0·850 in all proportions; from 0·850 to 0·880 they require five times, and from 0·880 upwards, ten times their weight of solvent, and all the solutions may be cooled to the ordinary laboratory temperature without any separation taking place. On the other hand, paraffin of 60° C. melting point, when boiled with alcohol, separates out almost completely when the liquid is cooled to 25° C., and at 0° C. it is absolutely insoluble. Softer paraffins are more soluble as their melting point falls, but even that melting at 34° is absolutely insoluble in alcohol at 0°.

A number of experiments carried out on various known mixtures of paraffins and paraffin-free oils, by dissolving 20 grammes of the substance in 100 c.c. of absolute ethyl alcohol, cooling the solution for two hours in melting ice, and filtering through a double filter, gave very satisfactory results: the extracted paraffins having within a degree or two the same melting point as the original, and the oils on distillation furnishing, up to the very last, distillates which remained liquid when allowed to fall on a piece of ice.

The composition and properties of **asphalt** and **asphalt-rock** have been given in Section III. (p. 218 *et seq.*). In Spon's *Encyclopædia*, it is stated that asphalt for varnish making should dissolve wholly, or with the exception of 4 or 5 per cent. of earthy matter, in carbon bisulphide, chloroform, oil of turpentine, or coal-tar naphtha of high boiling point. It should have a conchoidal fracture and brilliant lustre, and should yield a light brown powder. An angular fragment should not lose its shape, even at the edges, in boiling water, and should only begin to melt at 150° C. When adulterated with coal-tar pitch, the asphalt has a less brilliant fracture, and has an adamantine or metallic lustre instead of the ordinary resinous appearance. When fused at the lowest possible temperature, such adulterated asphalt has a granular pasty appearance and feeling and will not draw out into even and transparent brown threads, as pure asphalt does.

W. H. Delano[1] states that bitumen for mixing with asphalt rock should be perfectly black, "not brilliant," and at 70° F., should have the consistency of beeswax. "The best way to test the quality is to draw it out in threads; the longer they stretch the better the sample." The physical characters of bitumen from Trinidad and Bermudez (Venezuela) at different temperatures have been given as follows:—

	Trinidad Bitumen.	Bermudez Bitumen.
At 60° F.,	Hard and brittle.	Compressible.
,, 75°,,	Can be slightly bent.	Viscous and malleable.
,, 100°,,	Does not flow, but is easily bent.	Flowing, and can be drawn out into hair-like threads.
,, 189°,,	Flowing point.	Fluid.

Durand-Claye has proposed the following process for distinguishing between natural asphalt and coal-tar pitch:—

5 c.c. of petroleum spirit is added to 1 gramme of the sample and shaken up repeatedly. Filter, and add sufficient petroleum spirit to 5 or 6 drops of the filtrate to make up 5 c.c. Coal-tar pitch produces a greenish fluorescence which is seldom observed in specimens of mineral asphalt, and a similar fluorescence is imparted by the former to its solution in glacial acetic acid, turpentine, or chloroform. After shaking up with an equal bulk of rectified spirit, the mixture is allowed to settle, when the petroleum spirit, strongly coloured, will float on the top, the lower layer of alcohol being golden yellow in the case of coal-tar pitch, whilst, if the sample consists of natural asphalt, it will be either colourless or pale straw-yellow. If much volatile oil is present, the alcohol will be of a rather darker yellow than otherwise. A preferable test, proposed by the same author, consists in digesting the sample in carbon bisulphide, filtering the solution, evaporating the filtrate to dryness, and heating the residue until it becomes hard and brittle when cooled. To 0·1 gramme of this residue, in a stoppered tube, add 5 c.c. of fuming sulphuric acid, agitate, and allow to stand for twenty-four hours. Then add 10 c.c. of water one drop at a time, with continual stirring, and filter through paper. Natural bitumen gives no colouration or only a faint tinge, while coal-tar pitch gives a dark brown colour. If both are present, the proportions can be approximately determined by observing the depth of the shade produced (viewed by transmitted light).

C. Kingzett's process for determining the total amount of bituminous matter in asphalt rock and mixtures in which it is contained, consists in extracting the air-dried sample by means of freshly prepared Russian oil of turpentine, evaporating the solution, and weighing the residue. The insoluble matter is washed with ether, and the siliceous matter remaining after dissolving out the carbonates of magnesium and calcium with diluted hydrochloric acid, is washed and weighed. H. P. Cooper uses carbon bisulphide as the extracting agent. This solvent so completely removes the bitumen from Val de Travers asphalt, even when used in the cold, that the limestone residue is quite white. A good way to perform this test is to exhaust 20 grammes of the powdered sample with carbon bisulphide in a Soxhlet tube. If a correction is made for the water driven off at 100° C., the bituminous matter is indicated by the loss of weight. To verify the estimation, the carbon bisulphide can be distilled off and the residue heated to 100° C. until the weight is constant. To ascertain whether the sample is of good quality, the bitumen should be then heated to 220° C., the loss in weight being volatile oil ("petroleum"). This oil can also be determined in a better way by digesting the powdered sample repeatedly with cold alcohol until no turbidity is produced in the solvent by the addition of water, and weighing the residue. The carbon bisulphide should contain no free sulphur. Chloroform or benzene (coal-tar naphtha) may also be employed. A dark-coloured residue, after extraction of the bitumen, indicates the presence of useless organic matter, the amount of which is ascertained by ignition of the weighed residue, re-carbonating with ammonium carbonate, re-igniting gently, and weighing. The loss indicates non-bituminous organic matter. When the residue is white, the bitumen may be determined by simple ignition, re-carbonating the lime, and weighing.

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[1] *Twenty Years' Practical Experience of Natural Asphalt*, 1893.

Miss Lynton[1] recommends the following method of analysing asphalt:—

"Water is first to be determined, if present, by drying in a water-oven to a constant weight. The finely-powdered sample, ½ gramme if rich in bituminous matter, several grammes if rich in mineral constituents, is digested over night, in a 4-ounce Erlenmeyer flask with 50 c.c. of petroleum ether. The solution is decanted on to a weighed filter contained in a 3-inch funnel having a tap in the spout. The residue in the flask is digested for two to three hours with fresh petroleum ether, which is decanted as before, and this process is continued as long as any colour comes away. Then the insoluble residue is transferred to the filter, dried and weighed, any traces adhering to the flask being estimated by weighing the flask. The portion dissolved by the petroleum ether is put down as 'petrolene.' The flask is rinsed with boiling turpentine, which is poured on the filter (replaced in the funnel), and enough boiling turpentine is poured on the filter to wholly submerge it, left to digest for several hours or over night, and then allowed to filter through. The digestion with boiling turpentine and filtering is continued as long as any colour comes away, and then the process is repeated with chloroform; after which the filter is again dried and weighed, and the loss is entered as 'asphaltene.' The filter is now burned with the contents, the ash is treated with ammonium carbonate to restore CO_2 to any lime which may have been formed, and the loss of weight is put down as 'other organic matter,' the remainder being 'mineral matter.'"

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[1] *Journ. Amer. Chem. Soc.*, xvi., 809-822.

SECTION X.

THE USES OF PETROLEUM AND ITS PRODUCTS.

General Review.—In the first section of this work, it has been mentioned that petroleum and natural gas have been employed in a primitive manner as sources of light and heat from the earliest times, and that the use of the crude oil for the treatment of wounds and cutaneous affections, while of equal antiquity, has been even more general. The latter application may indeed be said to have been at one time universal, for it appears from the accounts given by historians that as a remedial agent, petroleum was carried to distant countries from the localities where it was found, and was thus a not unimportant article of commerce.

For *pharmaceutical purposes*, crude petroleum is no longer in general use by civilised races, but as is well known, the product *vaseline* is very largely employed, both alone and as a vehicle for the external application of medicinal agents, especially when local action, rather than absorption, is desired. The physical and chemical characters of vaseline, which have been described in a previous section, indicate the superiority of this product over an animal fat for such purposes.

Vaseline forms a good protective coating for the surface of oxidisable metal, and as such is used to a very considerable extent.

The volatile product of petroleum termed rhigolene, has been found to be a valuable *anæsthetic,* particularly for local application to produce cold.

The *paraffin candle* has so completely superseded the old tallow "dip," and the beautiful translucent candles of white paraffin manufactured in many artistic forms by Price's Patent Candle Company, J. C. & J. Field, and others, are so commonly employed, that it is unnecessary to point out how important the solid hydrocarbons contained in petroleum and shale oil have become to the candlemaker. Paraffin of low fusing point is also burned in specially constructed lamps.

As *illuminating agents*, the liquid products of petroleum are used under various conditions. The most important of these products, commercially, is kerosene, but both the more volatile and the less volatile are also largely employed in suitable lamps. Petroleum products and crude petroleum constitute an important source of light in their employment for (1) the production of "*air gas*" or *carburetted air*, (2) the manufacture of *oil gas* and *carburetted water gas*, and (3) the *enriching of coal gas.* For the first of these purposes, gasoline is needed; for the second, crude petroleum, various petroleum products, and shale oil are available—the liquid hydrocarbons being converted into permanent gas of high illuminating power; while for the third, either oil gas or the vapour of the sufficiently volatile hydrocarbons is required.

The *petroleum stoves* employed in this country for heating and cooking, are practically lamps of suitable construction, in which mineral oil is burned, but in the United States, the domestic use of gasoline as fuel is common.

In Russia, *petroleum residuum* (*astatki*) has to a great extent replaced solid *fuel* on steamships, in locomotives, and in stationary boilers, as well as for various industrial operations. In the United States, *natural gas* and *crude petroleum*—especially that of Ohio—are largely employed as fuel.

Petroleum products also constitute an important *source of power* in connection with motors of the gas-engine type, and the vapour of petroleum spirit is in one form of motor, employed similarly to steam.

The very general and increasing substitution of mineral oils for fixed oils and greases in the *lubrication* of machinery and the rolling stock of railways, indicates the importance of this application of petroleum products. For some purposes, preference is still given to "compound oils," which are mixtures of mineral and fixed oils, but for the lubrication of steam engine cylinders, a pure hydrocarbon oil should always be used, as in the presence of high-pressure steam, fixed oils are decomposed, with the production of free fatty acids and subsequent formation of metallic soaps.

The employment of petroleum products in obtaining light, heat, and motive power will be discussed in some detail in the following pages, but in order to complete this general review of the subject, reference should first be made to some of the less important applications of certain products.

Paraffin is used in the manufacture of wooden matches, the combustibility of the wood being increased by saturating it with the melted material, and it has been applied as a thin coating to the heads of matches to render them waterproof. Dr. Stenhouse has patented the application of paraffin to woollen fabrics, to impart additional strength and render them waterproof. It has been used for lining beer barrels, and is employed for glazing frescoes and paper, for saturating gypsum and fluorspar before turning them in the lathe or otherwise shaping them into ornaments, and in starching linen, to produce a gloss. Of recent years, paraffin, as well as mineral oil, has been used in laundry work, as an auxiliary to soap, on account of its detergent action. Paraffin is also employed as a preservative for stone and wood, and it forms a good protective coating for the labels and stoppers of bottles used for corrosive liquids. It is used in preserving eggs, and may be similarly applied as a preservative coating to meat, fruit, and flowers. Refined ozokerite is employed by French perfumers as a substitute for lard in the process known as "enfleurage," the almost entire solubility of the hydrocarbon in alcohol, and its non-liability to become rancid, giving it a great advantage over the animal fat. Paraffin forms an excellent electric insulator, and Mr. Joly finds that a good photometer disc-substitute may be made by placing a sheet of tinfoil between two suitably-shaped blocks of paraffin. The author has made use of this device, and can express a favourable opinion of it.

The possibility of obtaining from petroleum, *anthracene*, certain sulphonated compounds of considerable tinctorial power, and other substances available for use in the preparation of dyestuffs, has been demonstrated, though the processes have not been carried out commercially.

Many attempts have been made to introduce petroleum in a "*solidified*" form for use as fuel, but although the results yielded by some of the processes of manufacture have been of a promising character, the "briquettes" burning without fusion, this application of petroleum has not yet become of commercial importance. Considerable success, has however, attended the efforts of inventors to devise processes for the manufacture of *soaps* and *lubricating greases* containing a very large proportion of liquid hydrocarbons. Resin soap is found to be remarkably effective in the "solidification" of petroleum, and a decoction of the bark of *Quillaia saponaria* may be employed for the same purpose.

A *substitute for oil of turpentine* for mixing with varnishes and paints, is obtained from petroleum spirit by fractionation, and it has been found that other, less volatile, products of petroleum can also be used successfully in the preparation of paints. Petroleum distillates are sold under the names of "Patent Turpentine,"[1] "Turpenteen," and "English Turpentine," for use in mixing paints. Samples of these products, examined by the author, were found to resemble oil of turpentine in boiling point, and to have flashing points above 73° F. (Abel test).

Certain descriptions of solid bitumen, occurring in Kansas and elsewhere in the United States, dissolve completely in a suitable solvent, and the varnish thus formed, when applied to wood or metal, gives a hard, and yet sufficiently elastic, protective coating with a brilliant surface.

Petroleum spirit is largely used in the process of "*dry cleaning*," and in the extraction of grease from leather. It is also employed by floor-cloth manufacturers, and as a *solvent* in other industries.

A process for the purification of alcohol by means of hydrocarbons, is described by Dr. Squire in a paper read before the Society of Chemical Industry.[2] It is well known that oils and fats possess the property of absorbing the more or less volatile bodies which we know as odours, and this property has been taken advantage of in the present process. Parsons, of New York, in 1869, took out a patent for the purification of alcohol—90 per cent. at least—with paraffin, the mixture being heated by means of a steam coil with continual agitation. He then introduced warm water, so as to bring the mixture down to about 50 per cent. of alcohol, and allowed the whole to cool, with continued agitation. The paraffin, which separated in flakes, was then

[1] Patent No. 12,249, 1885. [2] *Journ. Soc. Chem. Ind.*, viii. (1889), 441.

filtered off from the purified spirit. In 1884, the subject was taken up by a Danish chemist named Bang, who became associated with M. Ruffin, of Paris. He pointed out that the fusel oil could be more effectively separated if dilute spirit were employed, and proposed the use of a volatile liquid product of petroleum as the purifying agent. Ultimately, however, a petroleum product of higher boiling point was found preferable. The details of the apparatus employed in carrying out the process on a commercial scale, and of a modified form devised in 1887 by Bowick, are given in the paper above referred to. The process was investigated in 1889 by Messrs. Newlands Brothers, to whom the author is indebted for the information that ordinary petroleum having a boiling point of 140° C. was used, and that the quality of the crude spirit (manufactured from molasses) was found to be very much improved by the treatment.

A method employed by Neff for producing *lampblack* from *natural gas* is described in *Dingler's polytechnisches Journal*, 1879, ccxxxi., 177. The product is obtained by the imperfect combustion of the gas in specially constructed burners, no less than 16 per cent. of the gas being converted into lampblack. The product contains about 95 per cent. of carbon, and is said to be well adapted for the manufacture of fine printers' and lithographic ink.

MINERAL OIL LAMPS.

The various forms of lamps in which mineral oils are burned, generally resemble those previously in use with fixed oils, but certain modifications have been rendered necessary by the comparative volatility and inflammability of mineral oils, and the high percentage of carbon which they contain. Thus, it is necessary to guard against any considerable heating of the bulk of the oil, and especially against the ignition of any inflammable or explosive mixture of petroleum vapour and air which may be formed in the upper part of the lamp reservoir, whilst at the same time, the illuminant must be continuously supplied in proper quantities to the flame, and the air admitted in such a manner as to produce a smokeless and odourless flame of high illuminating power. Special appliances are also usually provided to facilitate the lighting and extinguishing of the lamp, and in some cases, the lamp is fitted with an automatic extinguisher, which is brought into action in the event of the lamp being overturned.

In this country, the lamps first used with shale oil were those which had been constructed for burning "camphine" (rectified oil of turpentine). The best of the camphine lamps is said to have been Roberts' "Gem" lamp, which was on the Argand principle, and was fitted with the disc air-deflector known as the "Liverpool button." Mineral oil lamps were originally introduced into the United States from Vienna, but in 1859, as many as forty patents were granted in America for petroleum lamps and burners, and appliances in connection therewith. In 1852 or 1853, Stobwasser of Berlin introduced an Argand burner for use with coal oil, and a flat-wick burner for the oil obtained from lignite. The latter form of burner was adopted by Young's Paraffin Light and Mineral Oil Company for burning shale oil.

In 1865, J. and J. Hinks obtained a patent for their "Duplex burner," shown in Figs. 264 to 266, and in a slightly modified form, representing the most recent construction, in Fig. 267. In the patent specification, the wick-holders are described as being of flat, semi-cylindrical, elliptical or other shape. The burner is now fitted with an arrangement for raising the chimney gallery to facilitate lighting. The lifting is effected by turning a key, A, which acts through links, *a*, steadiness being secured by means of two guide-rods, B. The burner is provided with an automatic extinguisher consisting of two plates, *d e*, which slide on the wick-holders, C, and are brought together by a spring, E, acting through a forked lever, D, when a catch, *h*, is released. The automatic arrangement comprises a weight, F, hanging in a ring, *g*, on a lever carrying the catch, *h*, and is set for use, by depressing the lever until the catch is engaged. In case the lamp becomes overturned or much tilted, the alteration produced in the relative positions of the weight and the ring, *g*, releases the catch, and the plates, *d e*, extinguish the light. Extinction may also be

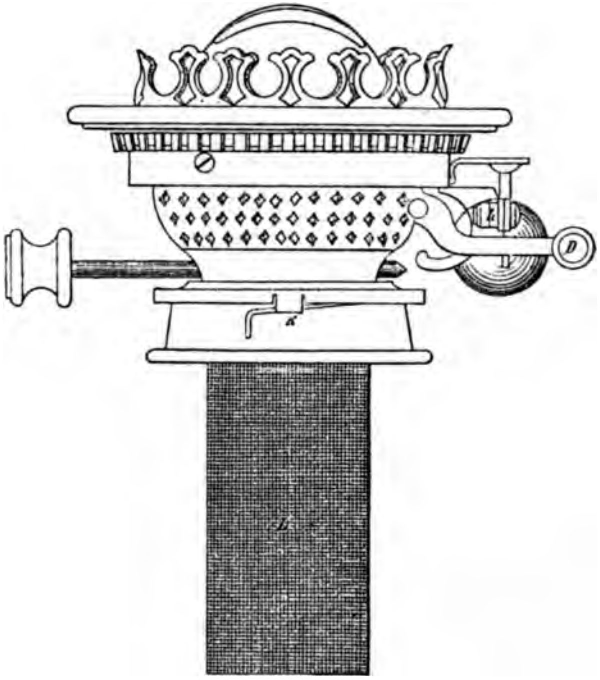

Fig. 264.

effected by pressing upon the outer end of the lever, D (Figs. 264 and 265), or in the arrangement shown in Fig. 267, by moving the weight. The burner is secured by a bayonet catch, K, and a ring of cork, J, is interposed between it and the reservoir to minimise conduction of heat. The "safety cage," L, surrounding the wick, is referred to on p. 677.

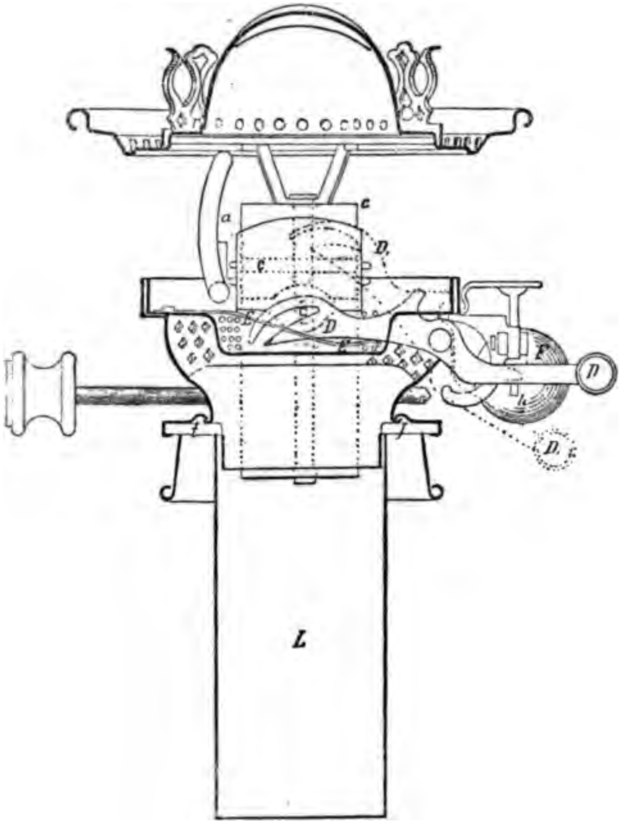

Fig. 265.

In the "Anucapnic" burner, patented in 1866 by T. Rowatt (No. 203), two distinct air-currents are directed upon the flame without the aid of the ordinary chimney, by means of two cones or deflectors, *d f* (Fig 268), the outer of which rests on the perforated flange of the inner. Air is supplied to the inner cone through apertures, *e*, in its support, *b*. Fig. 269 shows Rowatt's "Lorne" burner (also used without a chimney) in which the wick tubes are so inclined that the flames coalesce, the wicks being in contact below

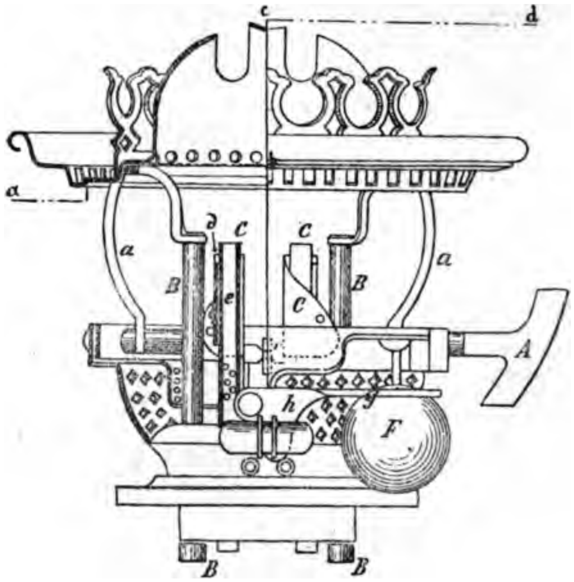

Fig. 266.

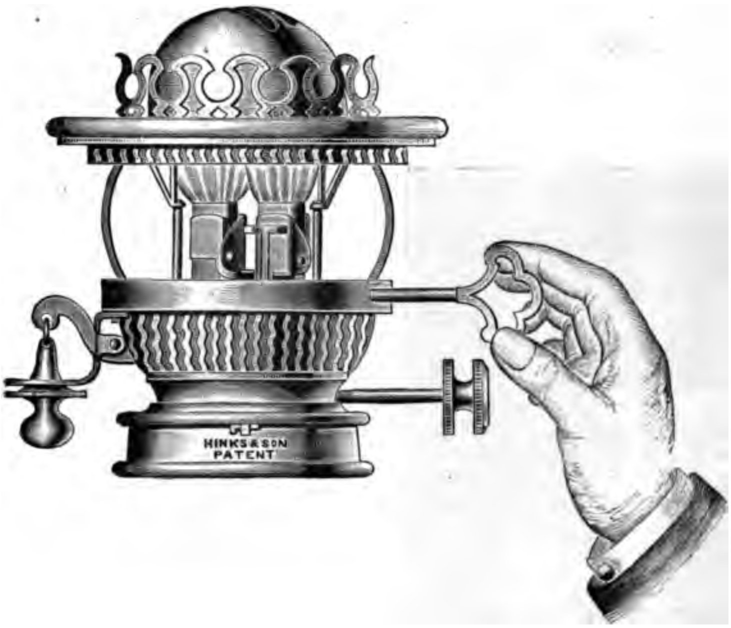

Fig. 267.

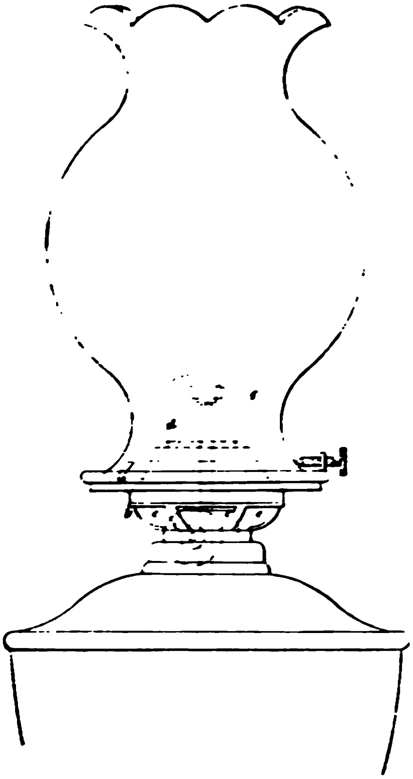

Fig. 268.

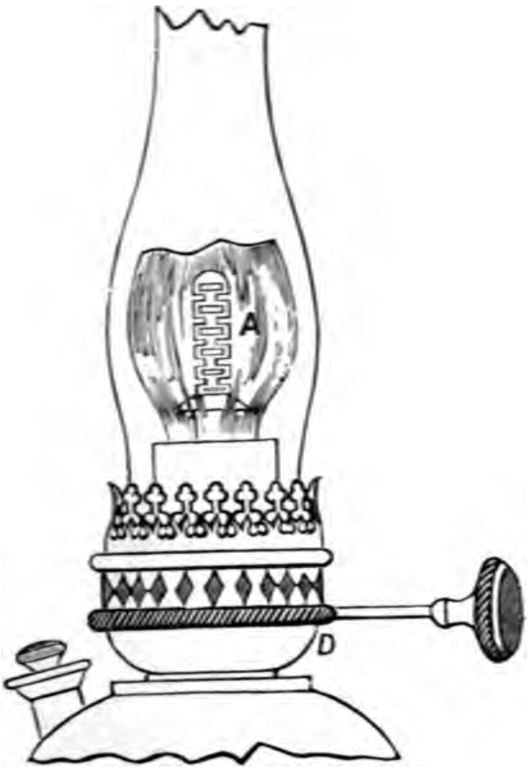

Fig. 270.

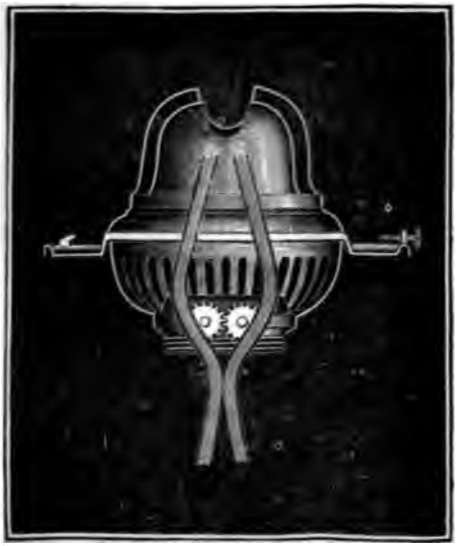

Fig. 269.

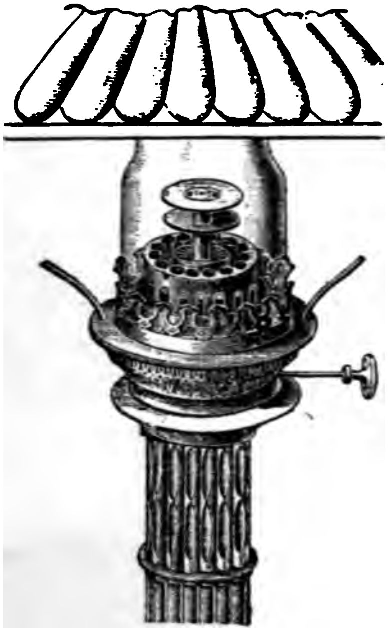

Fig. 271.

the burner. This arrangement is said to result in increased luminosity and enhanced capillary attraction in the wicks.

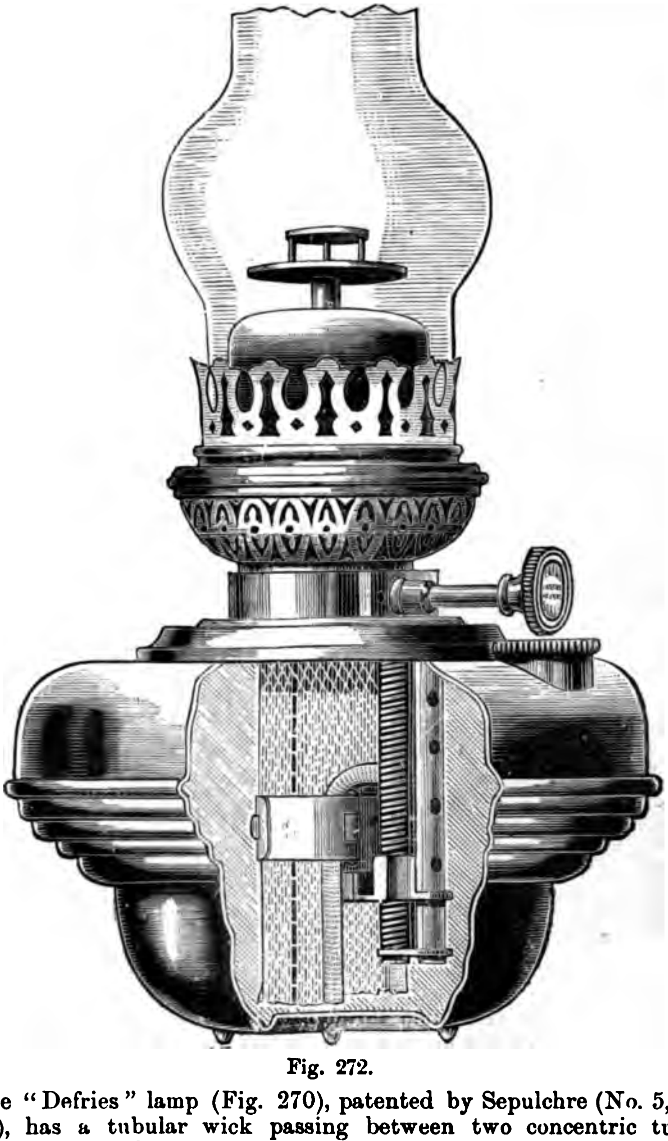

Fig. 272.

The "Defries" lamp (Fig. 270), patented by Sepulchre (No. 5,428, 1881), has a tubular wick passing between two concentric tubes, the outer of which is attached to the removable burner, and extends nearly to the bottom of the oil container, while the inner passes through the bottom of the oil container, and conveys air, through the burner, to the inner surface of the Argand flame. The outer tube serves to prevent outflow of oil in case the lamp is overturned. The burner is provided with an elongated air-diffuser, A, fitting into the inner air tube. The wick-adjusting mechanism is contained in a chamber screwing tightly into a concave receptacle, D.

In the "Lampe Belgé," there is also a central air tube passing through the oil reservoir, and an improved arrangement for raising and lowering the wick is provided.

Fig. 271 represents the "Mitrailleuse" burner, patented by Rettich. In has a number of solid cylindrical wicks arranged in a circle so that they may be adjusted simultaneously by one winder, and cannot be turned down so far as to drop into the reservoir. A double-disc air-diffuser is employed, and an arrangement for raising the chimney gallery to facilitate lighting is provided.

The "Lampe Veritas" is fitted with the air-diffuser and wick-raising mechanism illustrated in Fig. 272.

In the "Rochester" lamp, Fig. 273,[1] air is supplied to the inner surface of the Argand flame through a perforated tubular cap fitted outside the top of the air tube. The wick is attached to a tubular holder and is adjusted by means of a rod, as shown in the figure.

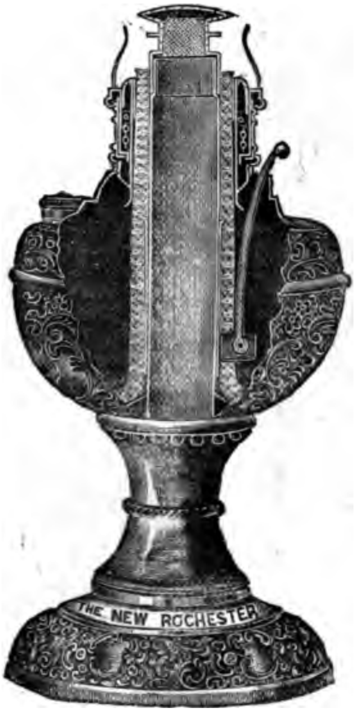

Fig. 273.

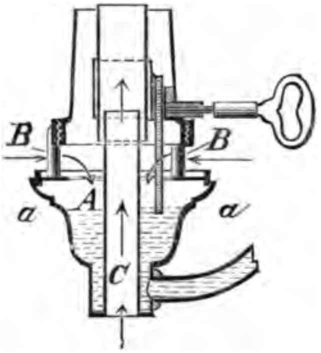

Fig. 274.

In the Wanzer lamp, which is used without a chimney, the necessary current of air is furnished by a small fan driven by clock work.

Fig. 274 represents a lamp, patented by Aria,[2] in which the oil is supplied from an upper reservoir as in an ordinary reading or railway roof lamp, or from a lower reservoir by a pump or piston as in the Carcel or Moderator lamp. A flange, *a*, in the reservoir, A, prevents overflow from the shaking of the lamp. A skeleton frame, B, supports the burner above the reservoir, and a tube, C, supplies air to the centre of the Argand flame.

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[1] United States Patent, No. 348,969, 1886.

[2] No. 15,768, 1888.

A flat-wick burner, patented by Aria,[1] has a perforated annulus instead of the skeleton frame, and the air supply is delivered through two semi-cylindrical tubes, the lower ends of which are covered by a cap with a slot which may be more or less closed to regulate the admission of air to the tubes.

In the "Sunlight" lamp (Figs. 275 and 276) of Ross and Atkins,[2] the principle of the inverted Argand burner so largely employed in the case of gas lamps, is adopted. The wick usually consists of an annulus of solid cylindrical wick supplied with oil by three flat wicks, or by a number of separate round wicks dipping into an annular reservoir fitted with a reflector as shown. Sometimes the wicks themselves constitute the burner. They are then so arranged that their ends form a circle. The air supplied to the burner is heated by passing over the surface of a porcelain cylinder, and is directed on to the flame by a cone.

Although in England and America, flat-wick burners have been far more largely used than the Argand form until within the last few years, flat wicks are rarely employed on the European continent.

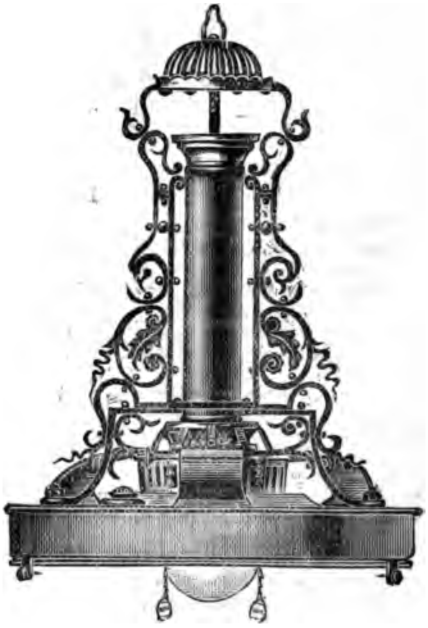

Fig. 275.

In Germany, the most commonly used burner is the "Cosmos," which is of the Argand type. It has neither the inner air tube passing through the reservoir nor the "Liverpool" button, and accordingly it is necessary to use with it a chimney which is much constricted near the base. The Argand burners introduced by C. H. Stobwasser & Co., Wild and Wessel, and Schuster and Baer, under the names "Victoria," "Phœnix," "Moon," and "Helios," are provided with disc air-deflectors. In the lamps manufactured by Kumberg for burning heavy Russian oil, especial attention has been given to the supply of air and to the conservation of heat at the point of combustion of the oil.

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[1] No. 8,995, 1890.

[2] Patent No. 2,019, 1889.

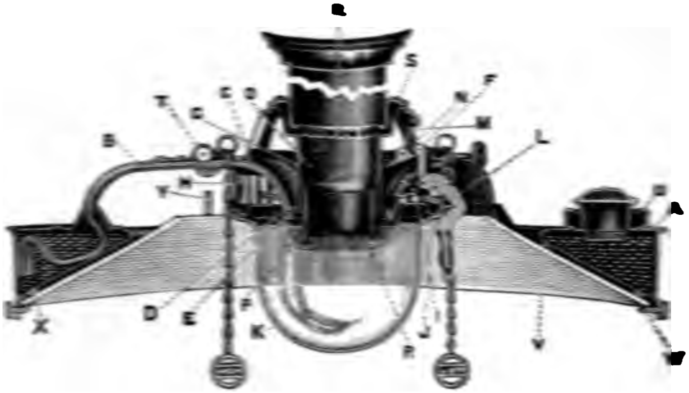

Fig. 276.

DESCRIPTION.

A. Section of annular reservoir.
B. Section of wick-tube showing feeding wick.
C. Wick tubes connecting feeding wicks to burning ring wick.
D. Burner cap carrying ring wick, bayonetted on to pins attached to wick tubes.
E. Ring for burning wick section in its place in burner cap.
M. Perforated conical ring fixed on top of wick tubes, and carrying the chimney, &c.
G. Extension of chimney projecting downwards from and secured to conical ring, perforated below for entrance to interior of flame of air which is heated in its passage by coming in contact with the outside of chimney.
H. Perforated box through which the air passes to the outside of flame.
I. Air cone which directs the outside air on to the proper part of flame.
J. Bezel jointed on to box H, which carries the glass bowl.
K. Glass bowl.
L. Lever catch and handle.
F. Connecting-rods.
N. Horse-shoe lever.
O. Chimney cone holder.
P. Chimney cone.
Q. Holes in chimney cone holder on which it is balanced on pins from horse-shoe lever, N.
R. Flame.
S. Regulating ring carried between M and G, having openings similar to and capable of being brought in line with openings in M. This ring is adjusted by pulling the labels "high" and "low."
T. Winder for feeding wick.
U. Oil filler and neck.
V. Reflector.
W. Screws on tabs secured to reservoir on which reflector rests.
X. Rubber pads to keep reflector from shaking.
Y. Screws to secure the frame of the lamp to the reservoir.

Makaroff's lamp for heavy oils has an annular reservoir connected by two tubes with a lower chamber, which extends upwards as a central cylinder, to the burner. Air is admitted to the latter through the space between the cylinder and an outer metal jacket, heat derived by conduction from the burner fittings being thus communicated to the air current, and the oil being at the same time warmed. An ordinary flat-wick burner is used, and the reservoir is enclosed in a conical metal vessel. It is stated that, owing to the protection from air draughts afforded by its shape, the lamp burns with a very steady flame, and is only slightly affected even by rapid movement. An improvement has been effected in this lamp by the addition of two fixed auxiliary wicks, one on either side of the principal wick. These are of unequal height, one of them only reaching as high as the burner, while the other extends to within a small distance from the flame and is protected from contact with it, by a metal cap.[1]

A mineral oil lamp has recently been patented by Schuelke, in which ordinary kerosene is burned in the form of vapour. The oil passes from the reservoir at the top of the lamp through a coil of brass tubing of small diameter, and is delivered into the vaporising chamber. Thence the vapour escapes downwards through a number of burner-tubes arranged concentrically so that an inverted Argand flame is produced. The vaporisation is commenced by burning a small quantity of methylated spirit in a cup beneath the burner, and is continued by the heat emitted in the combustion of the oil. The lamp is of the "suspension" type, and is intended for the lighting of large spaces.

Lamps in which a non-luminous flame is produced by burning kerosene vaporised by passage through a heated tube, are also employed for heating purposes.

The principle of the incandescence gas burner has recently been applied by E. Spiel, of Berlin, in the construction of a mineral oil lamp in which a Welsbach mantle is heated by a non-luminous flame, produced by the combustion of the vapour of ordinary kerosene. Experiments made in the author's laboratory, indicate that more than double the amount of light usually yielded by a given quantity of mineral oil, may thus be obtained.

Illuminating Power and Oil Consumption.—The actual lighting efficiency of a mineral oil lamp depends, of course, principally upon the quantity of oil burned in a given time, or, in other words, upon the size of the burner, but Argand burners almost invariably give more light in proportion to the oil burned, than duplex or single flat-wick burners. An extended series of experiments made in 1879 by the author and his brother, Mr. T. Horne Redwood, indicated that with the principal lamps then in use, the oil consumption was from 45 to 65 grains per candle light per hour, whilst, in a more recent series of tests, carried out with the assistance of Mr. Robert Redwood, with the ordinary forms of tubular and flat-wick burners, the consumption was found to range from 41 to over 70 grains.

The considerable diminution in the light afforded, which is sometimes experienced in the use of mineral oil lamps, may be due to the imperfect construction, or defective or dirty condition of the burner; to the use of a reservoir of insufficient diameter, resulting in a depression of the oil level which soon overtaxes the capillary power of the wick; to the employment of an inferior wick; or to the unsatisfactory quality of the oil.

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[1] *Dingler's polytech. Journ.*, 1890, cclxxv., 568.

The relative illuminating powers of various descriptions of mineral oil are largely dependent upon the conditions under which the oils are burned. The lamps commonly in use were designed for burning American kerosene and Scottish paraffin oil, and do not give equally good results with Russian kerosene. Burners and chimneys have been made in Germany with special reference to the requirements of Russian oil, but have not been generally adopted.

The character of the wick, the dimensions of the chimney, and the size and shape of the oil reservoir, are factors of only slightly less importance than the form of the burner. The temperature at which the oil is supplied to the wick, also affects the result. Even when every effort is made to establish uniform conditions for testing purposes, a number of burners of similar description will often be found to exhibit differences with the same oil.

No burner has been selected by common consent for use in making comparative tests of mineral oils, nor have any other testing conditions been agreed upon. Comparisons of the various mineral oils of commerce have been made from time to time, and some of the results obtained have been published, but from what has been already stated, it will be evident that such results must be of very limited value, and may even be misleading, for it is extremely difficult, if not impossible, to reproduce the average conditions under which mineral oils are used by the various classes of the community.

It will be obvious that similar difficulties stand in the way of instituting any precise comparison between the cost of mineral oils and of other illuminating agents; nevertheless, certain general conclusions may be arrived at.

According to the experience of the author and his brother, the average consumption of oil per candle light per hour, in the case of duplex burners with an illuminating power of about 28 standard candles, is about 50 grains, and in the case of Argand burners, with an illuminating power of about 38 candles, is about 45 grains, though with some lamps of both types, the oil consumption, in relation to the light afforded, is smaller than the respective quantities given. On the basis of a consumption of 50 grains, a gallon of oil, of 0·800 specific gravity, would give 1,120 candle-hours, and assuming that the lamp was giving the light of 28 candles, would last for 40 hours. Similarly, on the basis of a consumption of 45 grains, a gallon of such oil would give 1,244 candle-hours, and if the lamp were giving the light of 38 candles, would last for 32¾ hours.

The effective illuminating power of coal gas as used in dwelling-houses must of necessity be largely a matter of conjecture. The author has had the advantage of discussing the question with Mr. Lewis T. Wright, who is of opinion that the light obtained from gas in England is on an average 14 candles for a consumption of 5 cubic feet per hour, large districts being supplied with 18- or 19-candle gas. On this basis, which is equal to a consumption of 0·357 cubic foot per candle light per hour, 1,000 cubic feet of gas gives 2,801 candle-hours. In London, where the standard of illuminating power is lower, the results would be somewhat less favourable.

If, therefore, the consumption of oil per candle light per hour is taken at 50 grains, and the consumption of gas per candle light per hour at 0·357 cubic foot, it is evident that the present retail price of oil of 8d. per gallon is equal to a price of 1s. 8d. per 1,000 cubic feet of gas. Similarly, if the comparison is made on the basis of an oil consumption of 45 grains per candle light per hour, the gas must be sold at 1s. 6d. per 1,000 feet to be as cheap as the oil.

Gas may, of course, be burned under more economical conditions, but so may oil, the inverted type of Argand oil-burner consuming considerably less oil per candle light per hour, and the incandescence oil-burner less than half the quantity given above.

Lamp Globes. — In the diffusion globes of Blondel and Psaroudaki, the principle of the Fresnel lighthouse-lenses is applied. These globes are made of transparent glass, finely grooved on scientific principles, and their effect is to diffuse the light, with very little loss by absorption. The increase in illuminating power, in the field below

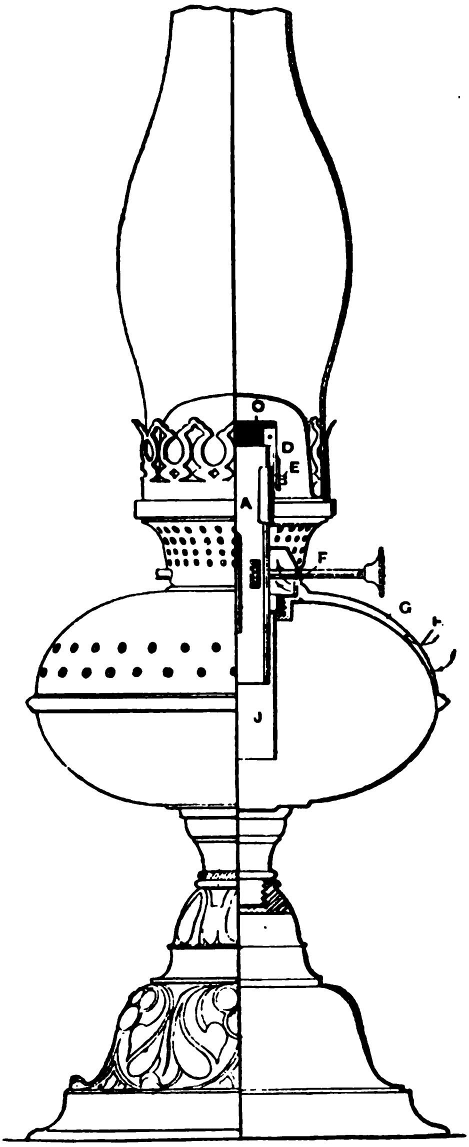

Fig. 277.

a horizontal line passing through the flame, is stated to be 12 per cent., and the loss by absorption, from 9 per cent. to 13 per cent. This loss is only about the same as occurs in the use of plain transparent glass, while ground glass or opal globes absorb from 35 per cent. to 70 per cent.

Extinguishers.—It has been already pointed out that some form of extinguisher is usually fitted to mineral oil lamps, and that of Hinks has been described. The earliest form appears to have been that with which the "Brighton" burner, patented in 1862, was provided. In this burner, the air-deflector or "Liverpool" button rested upon a pin, the withdrawal of which allowed the button to fall upon the wick and extinguish the flame.

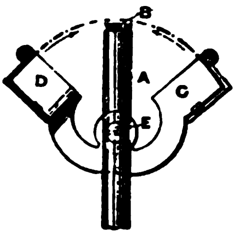

Fig. 278.

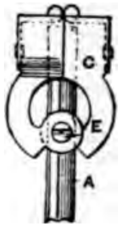

Fig. 279.

In Sherring's "Victoria" lamp (Figs. 277 to 279) the burner is furnished with two caps, C D, pivoted at E, which automatically close over the wick-tube, A, and wick, B, when the lamp is overturned. The upper part of the brass oil container is jacketed, an air-chamber, G (Fig. 277), being thus formed. A portion of the air supply enters at H, and in passing through the chamber is warmed, while the upper part of the container is cooled at the same time. The burner screws tightly at F into a cylinder or tube, J, which serves to prevent the outflow of the greater part of the oil in the event of the lamp being overturned.

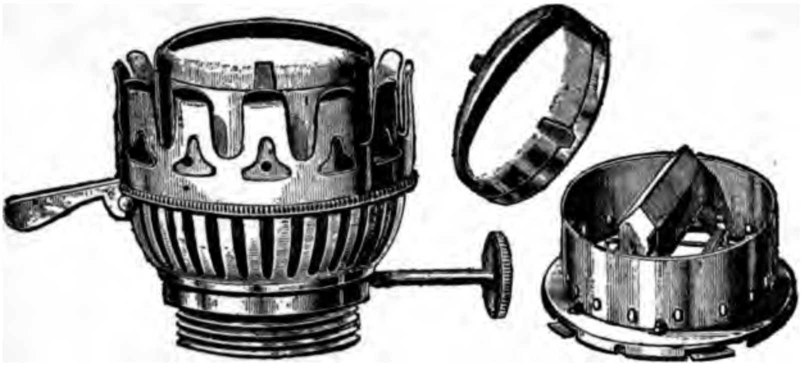

Fig. 280.

Postlethwaite's automatic extinguisher (Fig. 280) consists of two spring shutters which meet over the wick. The burner dome is made in two parts, the upper being sufficiently weighty to hold the shutters open. When this portion is displaced by the overturning of the lamp, the shutters are allowed to close. A lever for closing them at will is also provided.

In Devoll's "Water safety-lamp" the oil reservoir is surrounded by a water jacket, from which the water runs into a cap encircling the air-holes of the burner, when the lamp is overturned, the flame being thus extinguished.

Oil Supply.—To provide a large supply of oil for a lamp, Hampton & Sons have introduced the "Perpetual" lamp, the base of which contains, in a large reservoir, a week's or a month's supply. The lamp proper is supplied when necessary, from this reservoir, by a concealed force pump. Joseph Hinks & Son have introduced a somewhat similar arrangement, the base of a pedestal lamp forming the storage reservoir from which the oil is raised to a small oil-chamber beneath the burner, by the intermittent action of a piece of mechanism driven by a spring.

Safety Appliances.—To prevent the communication of flame to an inflammable or explosive mixture in the oil reservoir, Hinks & Son have, at the suggestion of the author, enclosed the wick beneath the burner in a wire gauze cylinder or cage, as shown in Fig. 264. The prolonged wick tube fitted to the lamps of Defries and others, is intended to serve the same purpose.

Wicks.—The value of a wick depends upon the capillary attraction which it is capable of exerting, and this varies with the quality of the cotton used, and the manner in which the wick is made. A loosely-woven wick of "long-staple" cotton gives far better results than a tightly-woven wick of "short-staple" cotton, and a series of experiments on wicks of the same width in ordinary use, performed in the laboratory of the author, showed that there was a variation in the proportion of 76 to 198, in the quantity of oil raised under similar conditions. The wicks manufactured by Joseph Morgan & Son are subjected to a process of washing, by which their capillary power is greatly increased. Wicks are found to absorb from 4 to 6 per cent. of their weight of moisture from the atmosphere, and as the capillary power is thus seriously impaired, it is advisable to carefully dry them before use. The choking of the wick which sometimes occurs, appears to be due to the absorption of water, at least in many cases, for Nakamura[1] finds that the wick recovers its power when dried.

Incombustible Wicks.—The wicks of the lamps employed by the Vestal Virgins are said to have been made of asbestos, and in the *Philosophical Transactions*, 1684, xiv., 806, Dr. Plot proposed the use of wicks of asbestos, or of gold or other metal wire, "which will lick up oyl as well as any other wick." A. and D. Gordon[2] patented the use of wicks of platinum, gold, silver, or copper drawn into threads, or of glass drawn into capillary tubes and bound into a bundle, and Roberts[3] employed cane, porous wood, or asbestos.

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[1] *Journ. Soc. Chem. Ind.*, 1883, 534.

[2] Patent No. 4,638, 1822.

[3] Patent No. 10,842, 1845.

In 1887, Bondini and Tubini patented (No. 10,502) the use of an ordinary cotton wick protected at the end or tip by enveloping it in a capsule or sheath of wire gauze or perforated sheet metal. A wick patented by Heinrichs, consisted of an asbestos tip forming the burner, an intermediate portion of mineral substance, and a lower portion of felt. The "Phœnix Perpetual" lamp wick is prepared by treating the upper end of a cotton wick for a length of about an inch, with an incombustible material. In the Benson-Lee lamp, there is a carbon burner supplied with oil by a cotton feeder-wick. The burner is of the Argand type, and the carbon ring is mounted immovably in a brass cell. The lamp is so constructed that on being overturned, outflow of oil cannot occur. The adjustment of the flame is effected by controlling the air-supply, and the lamp is extinguished by cutting off the air-supply. Wicks of the ordinary description are usually adjusted by toothed wheels fixed on a spindle which is turned by a milled head. In some cases, the wick is carried by a tube or frame, which is raised and lowered either by a rack and pinion, or by a worm cut on the burner tube (the movement being effected by revolving the burner), or by a sliding rod or flexible wire.

Lamp Accidents.—The subject of lamp accidents, to which much attention has recently been directed, was experimentally investigated as long ago as 1871, by Dr. Chandler of New York. The experiments, however, bore more particularly on the occurrence of explosions produced by the ignition of a mixture of petroleum vapour and air in the lamp reservoir, and, as pointed out by Peckham, Abel, and others, a large proportion of lamp accidents are simply due to the overturning or dropping of the lamp.

The following extract from a Report of Sir Frederick Abel and the author to Her Majesty's Chief Inspector of Explosives (1890), embodies the principal results of an investigation of the subject of accidents with mineral oil lamps which was conducted by Sir F. Abel, with the assistance of Dr. Kellner and the author :—

"(*a*) A large proportion of the accidents occurring in the use of mineral oil lamps are not due to the occurrence of explosions in the lamps. Many recorded instances of the breaking out of a fire, or the destruction of or injury to life, which are ascribed to lamp explosions, have evidently been caused by upsetting or dropping a burning petroleum lamp. The sudden cooling of a glass reservoir which has become much heated by the burning of the lamp may also result in fracture. The substitution of benzoline (mineral spirit) for mineral oil has in some cases probably caused the accident.

"(*b*) There are, however, numerous cases of accidents which have undoubtedly been due to the occurrence of explosions in lamps, and our experiments have enabled us to arrive at the following conclusions with respect to the causes of such explosions :—

"If the lamp be so carried or rapidly moved as to agitate the oil, a mixture of vapour and air may make its escape from the lamp in close proximity to the flame, and, by becoming ignited, determine the explosion of the mixture existing in the reservoir. This escape may occur through the wick-tube itself if the wick does not fit the holder properly, or through openings, of sufficient size to allow flame to pass them readily, which exist near the wick-tube in many burners. Some lamps have a tube inserted in the burner, through which the reservoir can be supplied with oil, and if this tube be not effectively closed it may constitute a channel for the passage of flame to the vapour and air mixture in the reservoir. The existence of an imperfectly closed filling aperture in the body or reservoir of the lamp also favours the occurrence of an explosion. A sudden cooling of the lamp, resulting from its exposure to a draught, may give rise to an inrush of air, thereby increasing the explosive character of the mixture of vapour with a little air already contained in the reservoir, and the flame of the lamp may at the same time be drawn or forced into the air space filled with that mixture, especially if the flame has been much reduced in size by lowering the wick, as the point of combustion is thereby brought nearer to the reservoir.

"If the practice is resorted to of blowing down the chimney with a view to extinguish the lamp, the effects already indicated as producible by exposure to a draught may be brought about. If the wick be lowered very much, or if for some other reason the flame becomes much reduced in size, so that it is burning beneath the dome, the lamp may become much heated, and its susceptibility to the effects described will be increased. Heating of the lamp reservoir is likely to be promoted if the air passages in the burner are obstructed by dirt or charred wick. If the wick is not long enough to reach the bottom of the oil reservoir, and the lamp is allowed to burn until the surface of the oil is scarcely level with the end of the wick, a proper supply being therefore no longer furnished to the flame, the wick may char down to and below the level of the toothed wheels in the wick-tube and drop into the reservoir while the upper end is still burning, and may thus cause an explosion. The accidental dropping of the still burning wick into the oil reservoir, through the wick being turned down below the level of the toothed wheels in the act of extinguishing the lamp, is also a fruitful source of explosions. If the flashing point of the oil used be below the minimum (73° Abel test) fixed by law, and even if it be at that point, or a little above it, vapour will be given off comparatively freely, but the mixture of petroleum vapour and air formed in the upper part of the reservoir of the lamp will probably be feebly explosive in consequence of the presence of an excess of the vapour. On the other hand, if the flashing point of the oil be comparatively high, the vapour will be less readily or copiously produced, and the mixture of vapour and air may be more violently explosive, because the proportion of the former to the latter is likely to be lower, and nearer that demanded for the production of a powerfully explosive mixture. If the quantity of oil in the lamp reservoir be but small, and the air space consequently large, the ignition of an explosive mixture produced within the lamp will obviously exert more violent effects than if there be only space for a small quantity of vapour and air, because of the lamp being comparatively full.

"Experiments have demonstrated that the burning of an oil of comparatively high flashing point is more likely to cause heating of the lamp than the use of an oil of comparatively low flashing point, in consequence of the higher temperature developed by the former, and of the greater difficulty with which some oils of that description are conveyed to the flame by the wick. It, therefore, follows that safety in the use of mineral oil lamps is not to be secured simply by the employment of oils of comparatively high flashing point (or low volatility), and that the use of such oils may even in certain cases give rise to dangers which are small, if not entirely absent, with oils of comparatively low flashing point.

"The character of the wick materially affects not only the illuminating power of the lamp but also its safety. A loosely-plaited wick of long-staple cotton draws up the oil freely and regularly, even when the supply of the liquid in the reservoir becomes almost exhausted, and little charring of the wick takes place if the oil is of good quality. But if the wick be tightly plaited, or if it be made of short-staple cotton of inferior capillary power, the oil will be less copiously supplied to the flame, and considerable charring of the wick, with largely increased heating of the burner, will ensue. The use of a wick which has not been thoroughly dried before immersion in the oil, or the capillary power of which has become impaired by prolonged use, may bring about the same result.

"Our experiments have also led us to the conclusion that a lamp explosion is not usually sufficiently violent to cause the fracture of an ordinary glass reservoir, although in several recorded cases it has had this effect; but although it may not, the alarm created by the explosion may lead to the lamp being dropped if it is being carried at the time, and if the reservoir is of glass, fracture will probably ensue and the liberated oil may become ignited."

The following suggestions as to the construction and management of mineral oil lamps, founded on recommendations made by Sir Frederick Abel and the author, were formulated and published by the Metropolitan Board of Works in 1885:—

1. That portion of the wick which is in the oil reservoir, should be enclosed in a tube of thin sheet metal, open at the bottom; or in a cylinder of fine wire gauze, such as is used in miners' safety-lamps (28 meshes to 1 inch).
2. The oil reservoir should be of metal, rather than of china or glass.
3. The oil reservoir should have no feeding place or opening other than the opening into which the upper part of the lamp is screwed.
4. Every lamp should have a proper extinguishing apparatus.
5. Every lamp should have a broad and heavy base.
6. Wicks should be soft, and not tightly plaited.
7. Wicks should be dried at the fire before being put into lamps.
8. Wicks should be only just long enough to reach the bottom of the oil reservoir.
9. Wicks should be so wide that they quite fill the wick-holder without having to be squeezed into it.

10. Wicks should be soaked with oil before being lit.

11. The reservoir should be quite filled with oil every time before using the lamp.

12. The lamp should be kept thoroughly clean, all oil should be carefully wiped off, and all charred wick and dirt removed before lighting.

13. When the lamp is lit, the wick should be at first turned down, and then slowly raised.

14. Lamps which have no extinguishing apparatus, should be put out as follows:—The wick should be turned down until there is only a small flickering flame, and a sharp puff of breath should then be sent *across* the top of the chimney, *but not down it.*

15. Cans or bottles used for oil should be free from water and dirt, and should be kept thoroughly closed.

Dr. Fock, in a lecture delivered in 1888 before the Prussian Industrial Society, on experiments made by the German Standards Commission, stated that the pressure resulting from the explosion of a mixture of petroleum vapour and air in a *closed* vessel may be as high as 14 atmospheres (210 lbs. per square inch), the most violent explosions apparently occurring at about 8° C. (14·4° F.) above the flashing point of the oil. He recommended the use of metallic or other unbreakable reservoirs, but considered that the risk of fracture of the reservoir was small, as the pressure was relieved through the wick tube. Even a cracked reservoir was found to withstand the pressure.

Ships' Lights.—The lamps employed for ships' lights and for the lighting of railway carriages must be of special construction in order to prevent the extinction of the flame by wind or water. In one form, the draught is produced by a tapering metal chimney, and the flame is supplied with air which enters a chamber between two plates at the back of the lantern, through two vertical tubes about one-third the height of the chamber and half an inch or more in diameter. Wire gauze is fitted to the lower end of the tubes to further break up the air current. The products of combustion pass up the chimney and impinge on an inverted cone, round which, and under a covering plate, they escape. The air supply is thus practically independent of the force of the wind, and any extra air current striking on the lantern rather assists in drawing away the products of combustion.

SPRAY LAMPS.

For lighting large areas, especially in the open air, blast or spray burners have been introduced. Figs. 281 and 282 represent an improved form of the Lucigen lamp, originally patented by Lyle and Hannay.[1] A, is the oil tank; B, the union for the compressed air, and the cock for regulating the supply; C, a moisture trap for water separated from the oil; D, a blow-off cock; E, a flexible tube for the air connection; F, the burner tube, carrying oil from the tank and having a nozzle, 13; G, the oil valve; H, the air valve; I, the air tube leading to the coil heater; K, the combustion chamber with internal coil for heating the air; L, the tube for leading the heated air to the burner; M, the burner; N, the oil valve and tube for the pilot light, 17 (this device was found to be practically useless, and has been abandoned). In the use of this lamp, a supply of compressed air is connected at B, a steady pressure of about 15 lbs. per square inch in the pipes, being required for efficient working.

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[1] Patents, No. 7,162, 1885; No. 1,626, 1886; Nos. 1,632 and 3,113, 1887.

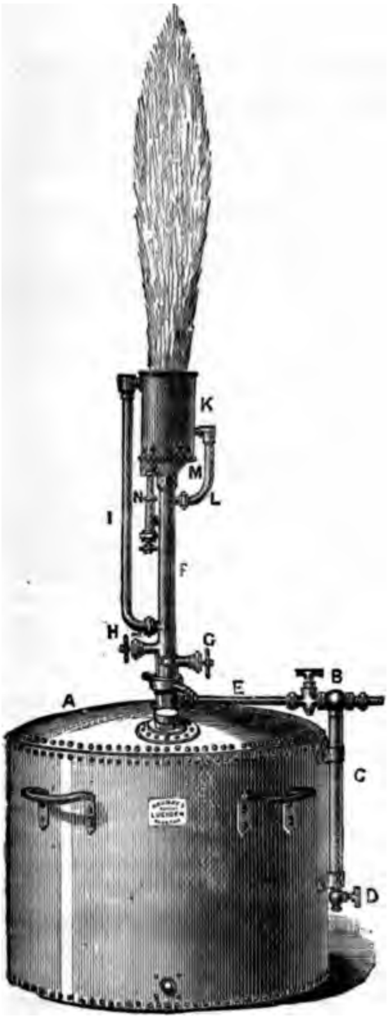

Fig. 281.

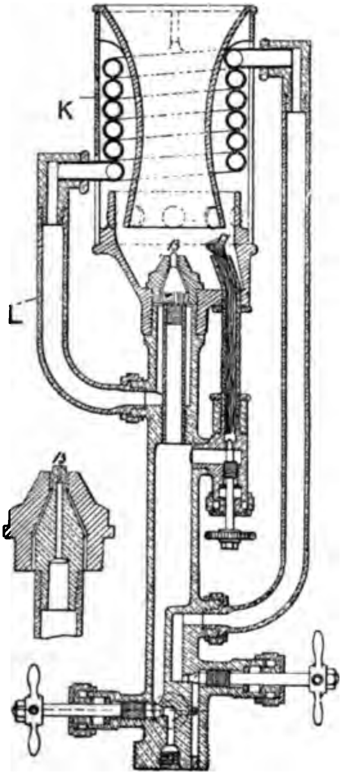

Fig. 282.

The oil is thus raised to the burner, and at the same time the air passes through the coil heater into the burner, where it heats and sprays the oil. The burner shown in the illustration has, in addition to an internal coil of several convolutions, an internal cast-iron baffle plate,

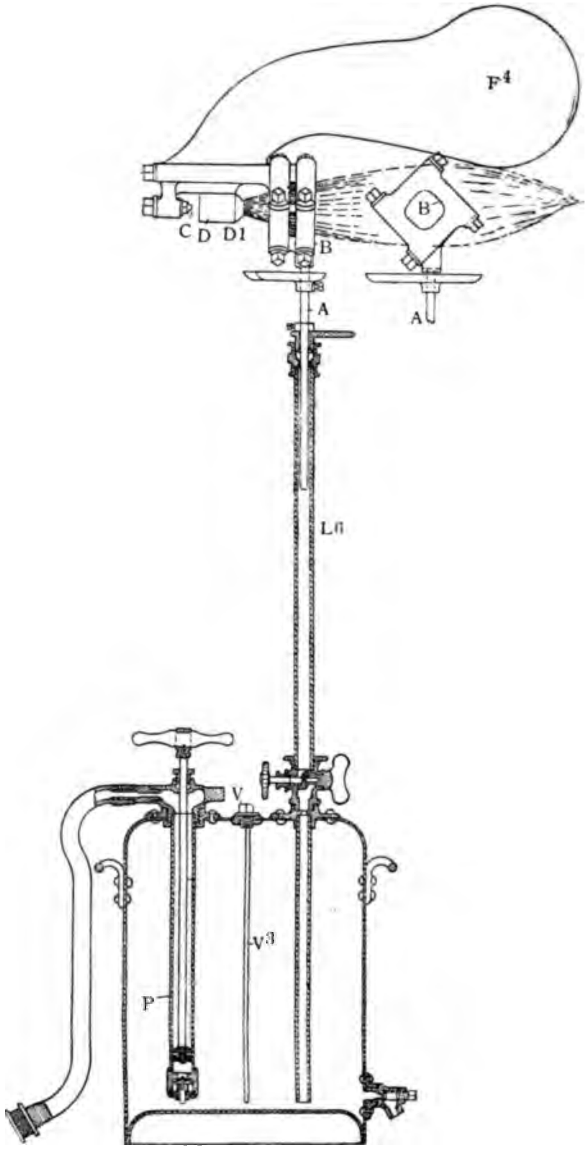

Fig. 283.

and an external wrought-iron casing. The latest form of the Lucigen lamp is provided with a far simpler combustion chamber, consisting of a single casting without any internal fitting, and with one external coil of air pipe. A Lucigen lamp of large size produces a solid tapering flame, about 3 feet in length and 9 inches in maximum diameter, with an illuminating power of 2,000 to 2,500 candles. Such a lamp consumes about 2 gallons of heavy mineral oil per hour.

The principle of the improved Lucigen lamp has been applied in the construction of burners for steam raising, rivet heating, &c. The rivets used in the building of the steamships "Campania" and "Lucania" were thus heated, and a similar system of heating was employed by Sir William Arrol in the construction of the Forth Bridge.

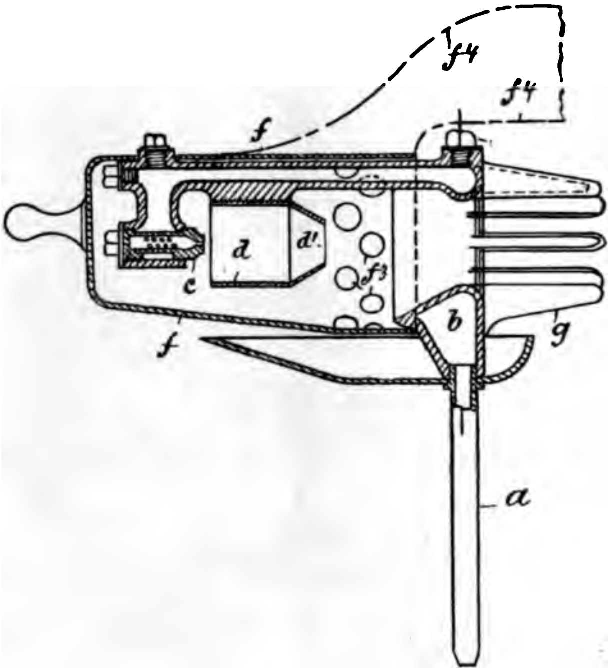

Fig. 284.

In the "Wells" light (Figs. 283 and 284), patented by Wallwork and Wells[1] the oil is raised to the burner by compressed air. The reservoir is charged by means of a pump, P; and a screw-plug, V, vertically grooved so that air may be admitted by turning it, is fitted with a rod, V^3, by which the height of the liquid may be ascertained. The usual form of the burner is shown in Fig. 284, and consists of a hollow casting, *b*, in which are fitted a nozzle, *c*, and a cone, *d*, d^1. Hollow gills, *g*, increase the heating surface, and a cover, *f*, with air-holes, f^3, is fitted round the casting. The oil becomes vaporised in the casting and is burned in admixture with air which the outrush of vapour draws into the cone. The burner may be fitted with a wind-vane, f^4, the tube, *a*, which carries the burner, being arranged to turn in the supply tube, L^6, so that the flame is kept in line with the wind.

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[1] No. 2,352, 1888, and Nos. 6,738 and 20,366, 1889.

The burner shown in Fig. 283, consists of two hollow rings, B, through which the oil passes; the nozzle, C, through which the vapour of the oil escapes; and the cone, D D^1, in which the oil vapour mixes with air before burning. The lamp is started, in the case of both burners, by burning a piece of tow soaked in oil in a cup beneath the burner.

MINERAL SPIRIT LAMPS.

Lamps of various forms are in use for burning petroleum spirit or benzoline. The ordinary domestic "sponge lamp" is a small chimneyless lamp, with a metal reservoir filled with sponge or other absorbent material into which the solid cylindrical wick passes. Only as much spirit as can be absorbed by the sponge, is poured into the reservoir. In some of the lamps in which such spirit is used, the illuminating agent is vaporised and burned at a jet with or without previous admixture with air. The simplest form of vapour lamp consists of a reservoir having at the top an opening communicating with the air, and at the bottom a tube extending downwards and terminating in an Argand burner. The reservoir contains an absorbent material which is saturated with gasoline, and from this the vapour, which is much heavier than air, flows downwards under sufficient pressure to give a steady flame at the burner. The costermonger's conical tin lamp, so largely used for producing an out-door light, is one form of a lamp introduced by Read Holliday.[1] The burner consists of a flat or annular chamber with perforations at the edge through which the illuminant passes. The reservoir is charged with benzoline or other mineral spirit, which flows down a tube to the burner and burns there without a wick. The supply is regulated by a tap, or by the introduction of cotton wool or other fibrous material into the supply tube. The burner requires to be heated before use, as its action depends on the vaporisation of the escaping spirit.

LAMPS FOR SOLID PARAFFIN.

A convenient form of miner's lamp for burning solid paraffin of low melting point, has been introduced by Young's Paraffin Light and Mineral Oil Company. The lamp has no chimney, and consists of a little tin can with a projecting spout which forms the wick-tube. The flame is encircled by a copper ring which conducts heat to the paraffin and maintains it in a fused condition around the wick. The Cera Light Company employ readily fusible paraffin in ships' signal-lamps. The burner with which these lamps are fitted, has an airdeflecting cone, and the paraffin is kept fluid in the reservoir by a copper wire formed into a helix above the flame and passing down beside the wick-tube into the reservoir, where it is bent into a coil.

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[1] Patents No. 12,015, 1848, and No. 12,965, 1850.

Concluding Remarks.—In the limited space available in this work it has been impossible to describe more than a few of the appliances which have been introduced for the utilisation as a source of light of the various liquid products of petroleum, and for further information respecting mineral oil and spirit lamps the reader is referred to articles by the author in the second volume of *Chemical Technology*, edited by Messrs. Charles E. Groves and William Thorp, and published by Messrs. J. & A. Churchill.

As already mentioned in the introductory remarks to this section, the stoves supplied for the domestic use of petroleum products, in heating and cooking, are practically lamps, and no special description of them is necessary.

AIR GAS.

Air gas consists of an inflammable mixture of air and the vapour of a volatile liquid hydrocarbon, such as gasoline. The proportion of such vapour which air is capable of taking up, varies with the temperature and with the volatility of the carburetting material used. One hundred volumes of air will retain of the vapour of gasoline of 0·65 specific gravity, 5·7 per cent. by volume at 14° F., 10·7 per cent. at 32°, 17·5 per cent. at 50°, and 27·0 per cent. at 68°. Air charged with 735 grains of gasoline vapour per cubic foot, has been found to possess an illuminating power of 16·5 candles when consumed at the rate of 3½ cubic feet per hour in a 15-hole Argand burner. Air gas, besides being employed as an illuminating agent, is used in gas engines as a source of power.

Air carburetted with pentane, is used as the source of light for photometric purposes, in Mr. A. Vernon Harcourt's standard, and in Mr. Dibdin's 10-candle standard, which has recently been recommended for official use, in testing the illuminating power of the gas supplied by the London Gas Companies, by the Board of Trade Committee, appointed in 1891, to inquire into and report upon the subject of the standards to be used for testing the illuminating power of coal gas.

The following is a description of experiments performed by the author, with the assistance of Mr. Blundstone,[1] with a view to the determination of the manner in which crude petroleum and certain volatile petroleum distillates evaporate when subjected to a current of dry air. Though carried out in connection with an investigation relative to the formation of an inflammable or explosive atmosphere in tank steamers, they bear on the question of the production of air gas. In these experiments, dry air was caused to bubble slowly through the liquid in a series of graduated tubes maintained at a constant temperature. The volume of air which had travelled through the whole of the tubes, and the quantity of liquid which evaporated from each tube, were ascertained at intervals, a set of determinations being made at temperatures of 40°, 60°, 80° and 100° F.

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[1] *Proc. Inst. Civ. Engineers*, Feb., 1894.

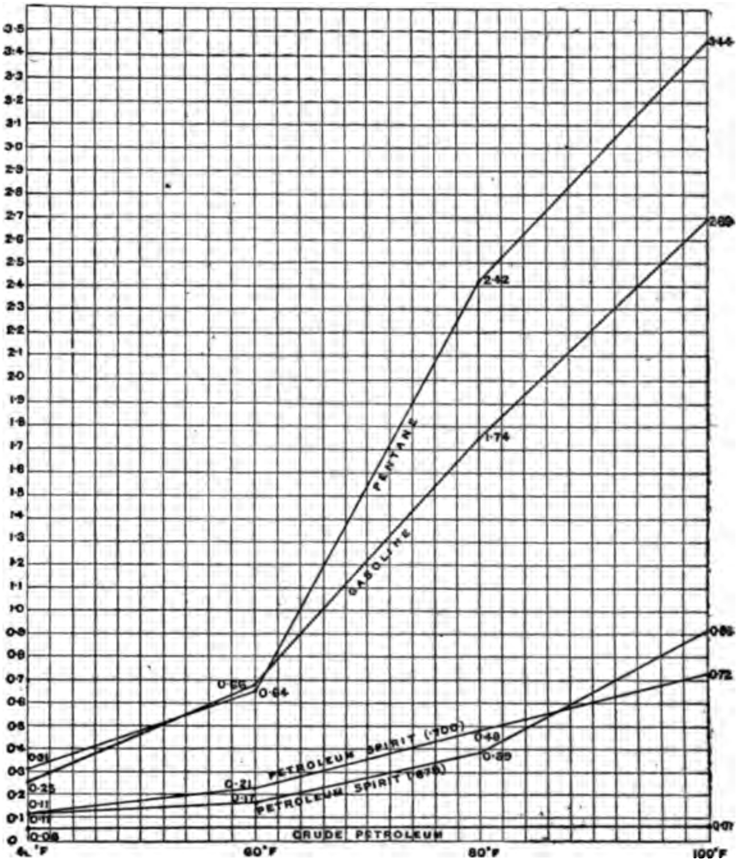

Fig. 285.

The results obtained are given in the following tables, and the volume of each liquid evaporated by 100 volumes of air (based upon the first set of readings at each temperature) is shown in Fig. 285:—

TABLE LXII.—Pentane.

Temperature of Liquid.	Volume of Liquid.	Volume of Air passed through the Tubes.	Vols. of Air to 1 volume of Liquid.	Volume of Liquid evaporated by 100 volumes of Air.						
				Tube 1.	Tube 2.	Tube 3.	Tube 4.	Tube 5.	Tube 6.	Total.
° F.	c.c.	Litres.								
40	51·85	0·85	16·4	0·24	0·035	0·024	0·011	Nil	Nil	0·31
40	51·85	2·0	38·6	0·215	0·040	0·022	0·013	0·005	,,	0·30
40	51·85	3·35	64·7	0·191	0·041	0·024	0·014	0·010	0·004	0·28
60	45·1	0·9	19·9	0·42	0·11	0·05	0·04	0·02	Nil	0·64
60	45·1	3·8	84·2	0·20[1]	0·15	0·09	0·06	0·02	0·03	0·56
60	45·1	5·4	119·7	...	0·13[1]	0·10	0·07	0·04	0·03	0·37
80	41·7	0·7	16·7	0·91	0·50	0·30	0·26	0·26	0·19	2·42
80	41·7	1·8	43·1	0·41[1]	0·39	0·27	0·22	0·20	0·14	1·63
80	41·7	2·5	59·9	...	0·29[1]	0·26[1]	0·27[1]	0·26	0·20	1·28
100	31·1 (in 5 tubes)	0·9	28·9	0·75[1]	Not read	0·78[1]	0·62[1]	0·71[1]	0·58	3·44

[1] Tube empty before reading was taken.

TABLE LXIII.—Gasoline (Specific gravity 0·639).

Temperature of Liquid.	Volume of Liquid.	Volume of Air passed through the Tubes.	Vols. of Air to 1 volume of Liquid.	Volume of Liquid evaporated by 100 volumes of Air.						
				Tube 1.	Tube 2.	Tube 3.	Tube 4.	Tube 5.	Tube 6.	Total.
° F.	c.c.	Litres.								
40	46·53	1·6	34·3	0·181	0·037	0·018	0·012	0·006	Nil	0·25
40	46·53	2·75	59·1	0·163	0·049	0·029	0·016	0·012	0·007	0·27
40	46·53	4·0	85·9	0·142	0·05	0·03	0·017	0·016	0·01	0·26
60	44·7	0·9	20·1	0·40	0·12	0·06	0·05	0·03	Nil	0·66
60	44·7	2·15	48·0	0·28	0·11	0·07	0·05	0·05	0·03	0·59
60	44·7	3·55	79·4	0·21	0·11	0·07	0·05	0·04	0·03	0·51
80	46·9	1·0	21·1	0·59	0·32	0·30	0·20	0·18	0·15	1·74
80	46·9	2·05	43·7	0·37	0·26	0·24	0·17	0·14	0·12	1·30
80	46·9	3·9	83·1	0·20[1]	0·20	0·17	0·14	0·12	0·10	2·93
100	36·0	1·15	31·9	0·49[1]	0·50[1]	0·53	0·39	0·46	0·32	2·69

[1] Tube empty before reading was taken.

Note.—Rapid evaporation and distillation (with condensation of liquid in exit tube) occurred in experiment at 100° F.

TABLE LXIV.—PETROLEUM SPIRIT (Specific gravity 0·679).

Temperature of Liquid.	Volume of Liquid.	Volume of Air passed through the Tubes.	Vols. of Air to 1 volume of Liquid.	Volume of Liquid evaporated by 100 volumes of Air.						
				Tube 1.	Tube 2.	Tube 3.	Tube 4.	Tube 5.	Tube 6.	Total.
° F.	c.c.	Litres.								
40	47·7	0·9	18·8	0·09	0·01	0·01	Nil	Nil	Nil	0·11
40	47·7	1·8	37·7	0·09	0·01	0·01	,,	,,	,,	0·11
40	47·7	3·0	62·8	0·08	0·01	0·01	0·01	,,	,,	0·11
60	42·5	1·35	31·9	0·12	0·03	0·01	0·01	,,	,,	0·17
60	42·5	2·8	65·8	0·11	0·03	0·01	0·01	0·01	0·01	0·18
60	42·5	3·8	89·4	0·09	0·04	0·02	0·01	0·01	0·01	0·18
80	46·5	1·45	31·1	0·19	0·08	0·05	0·03	0·02	0·02	0·39
80	46·5	3·0	64·5	0·14	0·07	0·05	0·03	0·03	0·02	0·34
80	46·5	4·7	101·1	0·11	0·06	0·04	0·03	0·02	0·02	0·28
100	47·9	1·05	21·9	0·35	0·19	0·13	0·12	0·10	0·02	0·91
100	47·9	2·45	51·1	0·23	0·14	0·10	0·09	0·08	0·04	0·68
100	47·9	4·1	85·5	0·17	0·11	0·10	0·08	0·08	0·03	0·57

Note.—Slight distillation in experiment at 100° F.

TABLE LXV.—PETROLEUM SPIRIT (Specific gravity 0·700).

Temperature of Liquid.	Volume of Liquid.	Volume of Air passed through the Tubes.	Vols. of Air to 1 volume of Liquid.	Volume of Liquid evaporated by 100 volumes of Air.						
				Tube 1.	Tube 2.	Tube 3.	Tube 4.	Tube 5.	Tube 6.	Total.
° F.	c.c.	Litres.								
40	27·9	2·2	78·8	0·006	0·002	0·001	0·001	Empty	Empty	0·11
40	27·9	4·6	164·8	0·05	0·02	0·01	0·01	,,	,,	0·09
40	27·9	7·6	272·4	0·04	0·02	0·01	0·01	,,	,,	0·08
60	29·25	1·2	41·0	0·11	0·04	0·04	0·02	,,	,,	0·21
60	29·25	3·2	109·4	0·08	0·04	0·03	0·02	,,	,,	0·17
60	29·25	4·5	153·8	0·07	0·03	0·03	0·02	,,	,,	0·15
80	43·0	0·8	18·6	0·18	0·10	0·06	0·06	0·04	0·04	0·48
80	36·4	2·0	54·9	0·13	0·08	0·05	0·05	0·04	Empty	0·36
80	36·4	3·6	98·8	0·10	0·06	0·05	0·04	0·03	,,	0·28
100	44·5	1·2	26·9	0·22	0·13	0·12	0·11	0·07	0·07	0·72
100	44·5	4·2	94·3	0·12	0·08	0·07	0·06	0·05	0·04	0·42
100	44·5	7·3	164·0	0·09	0·06	0·05	0·05	0·04	0·03	0·32

Note.—Slight distillation in experiment at 80° F. Considerable distillation in experiment at 100° F.

TABLE LXVI.—Crude Petroleum (Specific gravity 0·801).

Temperature of Liquid.	Volume of Liquid.	Volume of Air passed through the Tubes.	Vols. of Air to 1 volume of Liquid.	Volume of Liquid evaporated by 100 volumes of Air.						
				Tube 1.	Tube 2.	Tube 3.	Tube 4.	Tube 5.	Tube 6.	Total.
°F	c.c.	Litres.								
40	30·0	1·4	46·6	0·019	0·019	0·012	0·012	Empty	Empty	0·06
40	30·0	2·7	90·0	0·016	0·016	0·013	0·011	,,	,,	0·055
40	30·0	4·0	133·3	0·113	0·011	0·009	0·009	,,	,,	0·042
100	32·1	1·9	59·1	0·037	0·018	0·009	0·009	,,	,,	0·07
100	32·1	3·7	115·2	0·027	0·014	0·009	0·009	,,	,,	0·06
100	32·1	5·6	174·4	0·020	0·018	0·011	0·008	,,	,,	0·05

Taking the first set of readings in the case of pentane, it is seen that the volume of liquid evaporated by 100 volumes of air was 0·31 at 40°, 0·64 at 60°, 2·42 at 80°, and 3·44 at 100° F., a progressive increase which indicates the effect of augmented temperature. The amount of evaporation from the individual tubes at 40° F. was (1) 0·24, (2) 0·035, (3) 0·024, (4) 0·011, (5) nil, (6) nil, so that the air was saturated in its passage through the first four tubes. On the other hand, if the totals of the three determinations at 40°, or at 60°, or at 80° are compared, it will be seen that as the volume of air in relation to a given volume of liquid is increased, the percentage of liquid taken up by the air diminishes in consequence of the air passing away not fully saturated. The amount of volatilisation, of course, also diminishes as the height of the liquid column decreases. The results show that although complete saturation of the air is a slow process, a very considerable amount of vapour is readily taken up.

THE CARBURETTING OF COAL GAS WITH VAPORISED HYDROCARBONS.

Professor Bunte[1] describes a number of experiments on the carburetting of coal gas by means of various hydrocarbons, notably of gasoline (boiling at 40° C. and consisting mainly of pentane), carburine (boiling at 69° and mainly consisting of hexane), and benzene (boiling at 80°). He observes that the results of experiments on the illuminating power of the enriched gas are modified by the nature of the burner used, and by the amount of gas burned in unit time. He recommends the use of benzene as a carburetting agent, and mentions the fact that an important source of it will be the liquid produced in the compression of oil gas.

According to Letheby,[2] an economy of from 40 to 50 per cent. resulted from the carburetting of coal gas with 10 grains of volatile hydrocarbon per cubic foot.

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[1] *Journ. f. Gasbeleuchtung*, 1893, xxxvi., 442.

[2] *Journ. Soc. Arts*, x., 87.

AIR GAS MACHINES AND CARBURETTORS.

Air gas machines usually consist of arrangements for passing air over a large surface of gasoline. The liquid may be contained in a number of shallow trays, or in spongy or porous materials, curtains of flannel dipping into the spirit being sometimes employed. Occasionally, the air is caused to bubble through the liquid. In all cases, the carburetted air must be used as it is made, for the volatilised hydrocarbons re-condense more or less on storage, and especially during passage through pipes.

The carburetting of air and the enriching of illuminating gas by hydrocarbon vapours, appear to have been first proposed by Lowe,[1] and processes for the same purpose were soon after devised by Mansfield and by Longbottom. Even when gasoline is used, fractional evaporation always occurs, so that after a time, the liquid remaining in the carburettor is found to be insufficiently volatile. The "metrical" carburettor of Jackson, introduced to overcome this difficulty, delivers a measured quantity of gasoline to the gas or air which passes through it, the proportion recommended by the inventor, in the case of air, being 3 to 6 gallons per 1,000 cubic feet, or in the case of gas, $1\frac{1}{2}$ to 2 gallons.

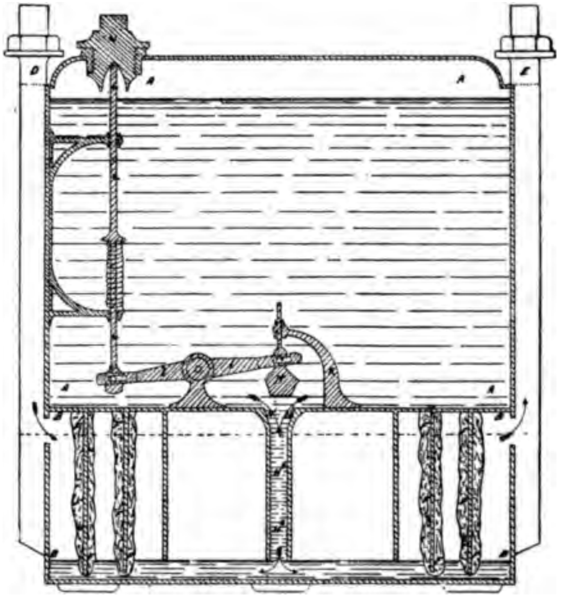

Fig. 286.

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[1] Patents No. 6,179, 1831, and No. 8,883, 1841.

In Müller's "Alpha" gas-making machine, the gasoline is exposed in a number of shallow trays, over which the air is forced by a rotary blower driven by a weight attached to a cord wound round a drum. A weighted lever keeps the drum revolving while the weight is being wound up.

Weston's carburettor[1] (Fig. 286) consists of a reservoir, A, from which the carburetting agent is supplied to a lower chamber, B, where a constant level is maintained. A plug, H, closes the connection between the chambers, A, B, when a plug, N, is removed for charging the upper one. The chamber, B, is divided into compartments by curved plates covered with spongy material, F, which absorbs the liquid. The air or gas thus traverses a tortuous path and becomes fully carburetted in passing from the inlet, D, to the outlet, E.

In Maxim's carburettor,[2] the gasoline or other enriching liquid is evaporated by heat, so that fractional evaporation or any variation of the amount volatilised, due to differences in temperature of the air or gas, is obviated. The amount of such evaporation is automatically adjusted according to the rate of consumption of the enriched gas. It has been found that coal gas is enriched, in this apparatus, to the same extent, whether a large or small number of burners is being supplied, and that no deposition of liquid occurs if the enriched gas be cooled to 50° F.

In Maxim's improved apparatus (Fig. 287), the gasoline is supplied from a reservoir at a suitable height, to the upper part of a chamber, G, warmed by steam or by hot air from a ring burner surrounding its lower part, and passes, as shown by arrows, over and through a number of perforated plates in its downward course. The upper end of the vessel is fitted with a tube, G^1, terminating in a cap through which slides a tube, J, carried by a gasholder, D, and having a series of apertures throughout its length. The air is supplied at E to a mixing-chamber, B, having in its casing some mercury, in which the gasholder rises and falls. When the gasholder reaches a certain height, its contents pass through apertures, formed in it at a suitable level, into a chamber, A, whence they pass away at F for consumption. As the gasholder rises with the tube, the perforations in the tube allow more or less of the gasoline vapour to enter the gasholder, so that the supply of vapour is varied according to the amount of gas used. The tube, J, is sometimes fitted, as shown, with a similarly perforated tube, J^4, which may be adjusted angularly or longitudinally, so that the openings may be more or less closed to further regulate the supply of gasoline vapour. In another arrangement, the tubes, J J^4, are replaced by a rod passing through the cap of the tube, G^1, and having tapering V-shaped grooves which permit passage of more or less of the vapour into the gasholder, according as their wider or narrower parts are above the cap.

The principal Metropolitan Gas Companies now extensively employ gasoline for raising the illuminating power of their gas. Fig. 288

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[1] Patents No. 3,301, 1875, and No. 3,865, 1880.

[2] Patents Nos. 703 and 2,508, 1889.

represents an arrangement for this purpose, patented by Maxim and Sedgwick.[1]

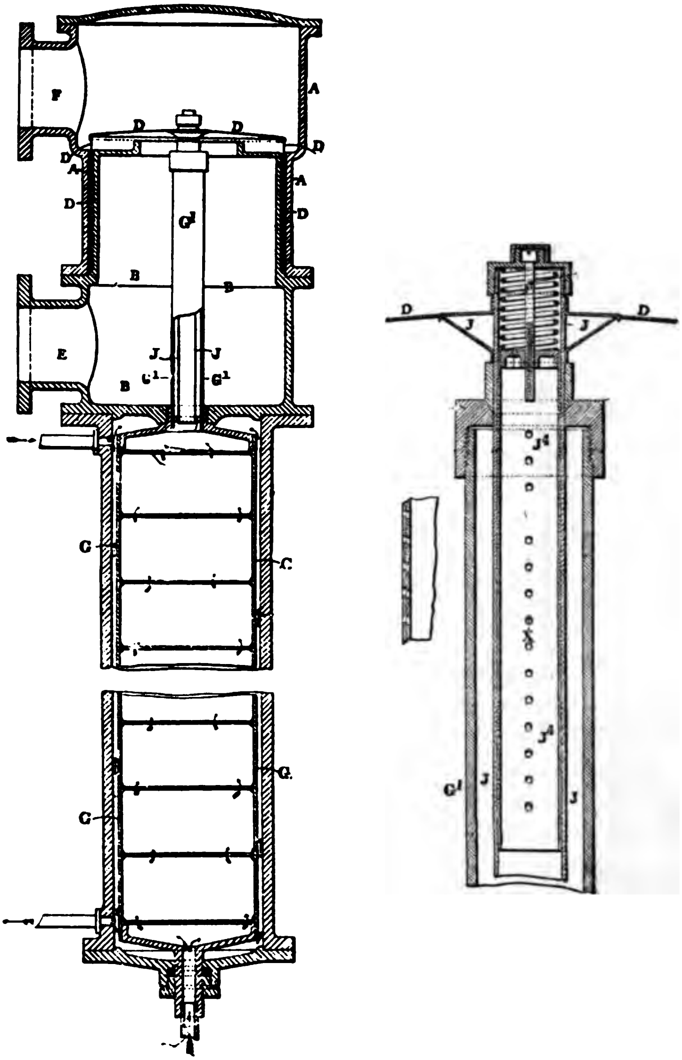

Fig. 287.

The gasoline is contained in a vaporiser, A, and is converted into vapour by steam supplied from a generator, B. The vapour may be delivered directly into the gas main, but is preferably mixed with a suitable quantity of gas drawn from the main at a convenient point, and returned to it after enrichment. The vaporiser is divided into three compartments by tube-plates, a^2 a^3, connected by tubes, a^4, and the hydrocarbon passes into it through a valve, *g*, from a raised tank. In the arrangement preferred by the inventors, the vapour produced passes out at *e* through a stop-cock or valve, into an injector. In escaping through the annular nozzle of the injector, the vapour draws a quantity of gas through a pipe from the main and mingles with it. The mixture is delivered through another pipe into the main, and the gas is thus enriched to any desired extent.

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[1] No. 2,559, 1890.

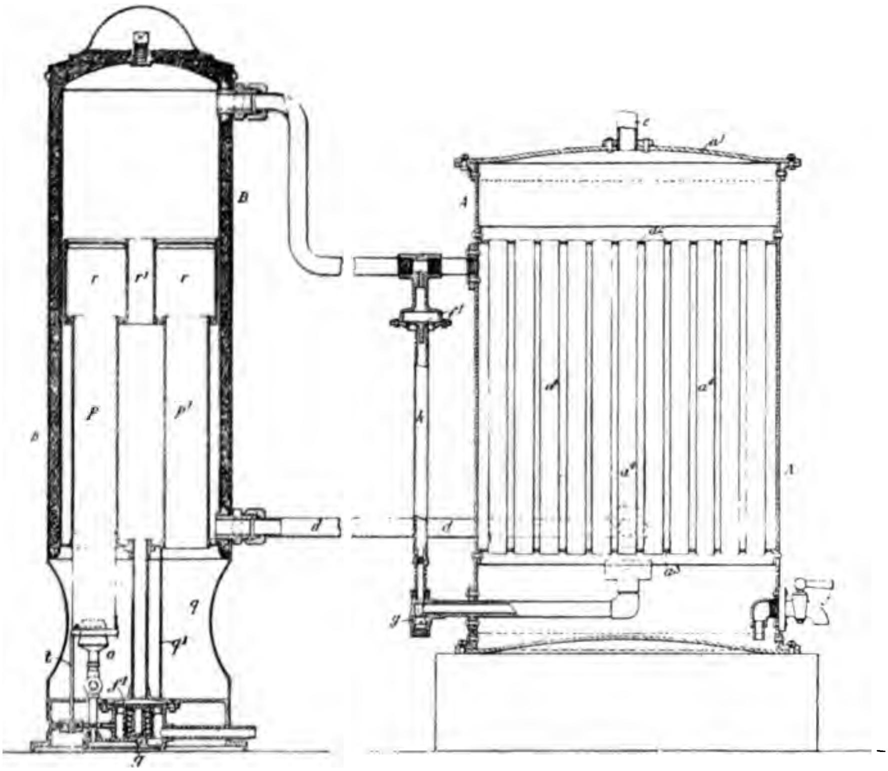

Fig. 288.

The steam generator, B, consists of an upper chamber containing the water, and a lower chamber in which the heating arrangements are enclosed. The hot products of combustion from a burner, *o*, pass upwards through flues, *p r*, and downwards through flues, *r* p^1, into a chamber, *q*, separated by a diaphragm, q^1, from the chamber containing the burner. They finally escape through the side of the chamber, *q*. The flue, *r*, is annular, and may have a tube or tubes, r^1, passing through it to increase the heating surface. The supply of gas to the burner is preferably regulated by a valve, *g*, controlled by a diaphragm, f^1, which rises or falls with any alteration of the pressure in the steam generator, B. The gas is re-lighted at the burner, *o*, by a continuously burning flame supplied from a tube, *t*. The steam passes into the middle chamber of the vaporiser and the condensed water returns to the generator, B, through a pipe, *d*.

The supply of spirit to the vaporiser is regulated by the pressure of the steam on a flexible diaphragm, f^1, connected with a valve, *g*, on the supply pipe, by a solid or tubular rod, *h*. Any liquid which accumulates in the vaporiser is drawn off at a cock, *j*.

Fig. 289 illustrates the "Simplex-carburettor" employed with the gas engines of Messrs. Delamare-Deboutteville and Malandin of Rouen, for producing air gas. Petroleum spirit of density 0·65 to 0·70 is placed in a reservoir, R, and thence flows through a graduated cock, D, into a column, E, surrounded by a casing, C, heated by the hot water from the jacket of the engine cylinder. This water has a temperature of 40° to 50° C. when it reaches the casing, C. Water from the casing falls in a light shower at F, and mingles with the spirit in the column, E. A spiral horse-hair brush, B, serves to break the oil up into spray. Each suction stroke of the gas-engine piston, acting through a non-return valve, S, draws air through the column, E, in which it becomes saturated with the spirit vapour. The water, dirt, and excess of spirit pass into a chamber, L, through a valve, V. An overflow pipe, N, keeps the water at a constant level. The water is stated to be of service in facilitating the spraying of the spirit, and removing dirt.

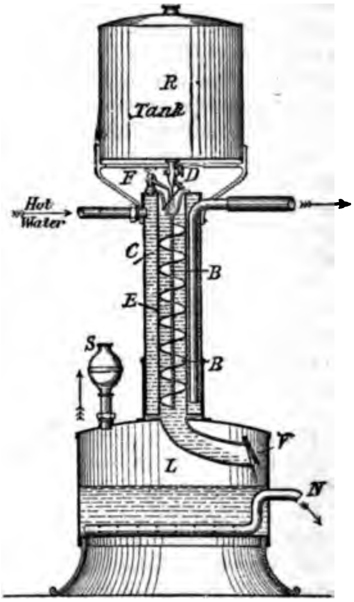

Fig. 289.

OIL GAS.

Oil gas is now very largely and increasingly used as an illuminating agent, both alone and in admixture with coal gas and water gas; it is also employed as a source of power in gas engines. On account of its high illuminating value, and of the fact that it suffers less deterioration on compression, than coal gas, it is employed for lighting railway trains, and ships, buoys, and lighthouses. For use in buoys, it is generally compressed to about 10 atmospheres, when it loses about 10 per cent. of its illuminating power from the condensation of the less volatile hydrocarbons, but still gives a light of from 40 to 50 candle-power.

For the lighting of railway carriages, it appears to have been first used in 1871 on the Silesian railways, and in 1876, it was introduced on the Metropolitan Railway. According to Mr. Thompson, the use of oil gas on the Metropolitan Railway is cheaper than that of coal gas.

The first oil-gas producer was made in England in 1815 by Taylor,[1] the gas being prepared by passing vegetable and other oils through highly heated pipes, but lighting by compressed oil gas was proposed as early as 1792 by Murdock. Faraday[2] examined the gas and by-products obtained by the process patented by Gordon and Heard[3] for producing a compressed portable gas.

In the manufacture of oil gas, the oil is slowly delivered into a retort heated to cherry redness, and is thus converted into permanent gas. The illuminating power of the gas depends upon the temperature of the retort, more gas being obtained when the retort is highly heated, but the product being of lower lighting value.

The colour of the gas, at the time of production, should be nut-brown, and the tar from the hydraulic main should not exhibit a greasy margin when dropped on white paper. If the oil be supplied to the retort too freely, or if the temperature of the retort be insufficiently high, the gas will be light brown or white in colour, and the greasy margin referred to will be formed; whilst, on the other hand, if too little oil be passed into the retort, or if the temperature be too high, the colour of the gas will be dark brown, and flakes of soot will be discernible.

On leaving the retorts, the oil gas passes into a main filled with water which removes the bulk of the tarry matters. Thence it flows, after further washing and cooling, into the gas holder. This purifying process is sufficient for gas used in engines, but when required for lighting purposes, the gas passes from the hydraulic main, through a water washer, and thence over a mixture of two parts of slaked lime and one part of sawdust. Having thus been freed from sulphur compounds, carbonic acid, &c., it is stored in a gasholder, and is thence pumped into portable receptacles at a pressure of 10 atmospheres.

In Great Britain, oil gas has until recently been usually made from the 'gas oil" obtained in the distillation of Scotch shale. This oil, which is intermediate between the burning and lubricating oils in respect to boiling point and density, has a specific gravity of 0·84 to 0·87. Now, however, an intermediate Russian oil known as solar oil distillate, gas oil imported from the United States, and ordinary kerosene, are all used for the purpose by the gas companies. Mr. Donkin states that

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[1] Patent No. 3,929. [2] *Phil. Trans.*, 1825, 440. [3] No. 4,381, 1819.

"in other countries various substances are successfully distilled to produce oil gas, such as linseed oil in Brazil, castor oil in Burmah, palm oil in West Africa, mutton-fat in Australia and South America, and, in general, fatty refuse of all kinds wherever it is found in abundance."

The tar obtained in the manufacture of oil gas, amounts to about 5 gallons per 1,000 feet, and is burned under the retorts. The liquid obtained by the compression of the gas, contains from 24 to 65 per cent. of benzene and toluene,[1] and is rich in normal olefines, but is practically free from paraffins. It amounts to about 1 gallon per 1,000 cubic feet. It appears to be well suited for the production of air gas, but is said to be mainly sent to Belgium for use in the manufacture of varnish.

Pintsch's oil-gas plant,[2] largely used for making gas for buoys, lighthouses, &c., is represented in Fig. 290. The retorts are of cast iron and D-shaped, the largest size being 6 feet 2 inches to 6 feet 4 inches long, 10 inches wide, and 9¾ inches deep. They are heated to a bright cherry-red and are worked in pairs, one being set above the other. The oil is run from a reservoir, B, into the upper retort, A, at one end, where it falls upon an iron tray, C, and the vapour passes into the hotter retort, D, beneath, where it becomes gasified. The gas passes through a tar separator, E, into the hydraulic main, and is further purified in the manner already described, about 80 cubic feet of gas being obtained per gallon of oil. The pressure in the retorts amounts to about 3 or 4 inches of water.

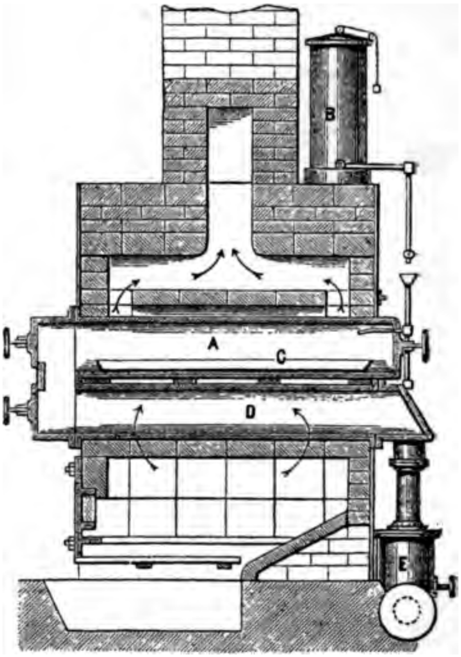

Fig. 290.

The Keith plant (Fig. 291) was the first applied to the production of oil gas for use in motors on the large scale. It is employed by the Commissioners of Northern Lights, at Langness Point, in the Isle of Man, for driving the Crossley engine in connection with the fog signalling apparatus. There is also an installation on this system on

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[1] Greville Williams, *Chem. News*, xlix., 197.

[2] Patents No. 3,101, 1873; No. 4,515, 1876; and No. 4,967, 1883.

Ailsa Craig Rock, in the Firth of Clyde, for the same purpose.[1] The central portion of the retorts is constructed as shown, and the oil is delivered into shallow cast-iron gutters, along which it flows into the hotter parts of the retorts, where it becomes gasified.

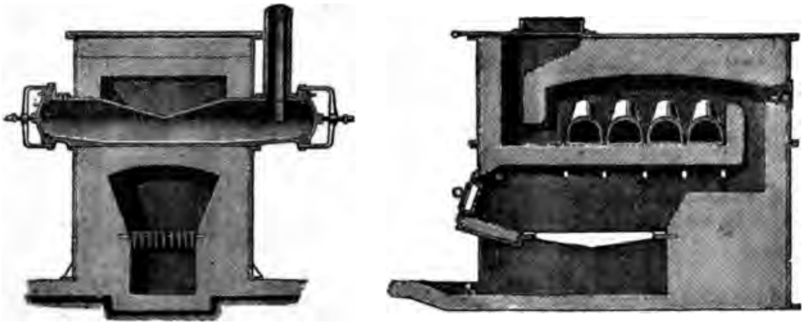

Fig. 291.

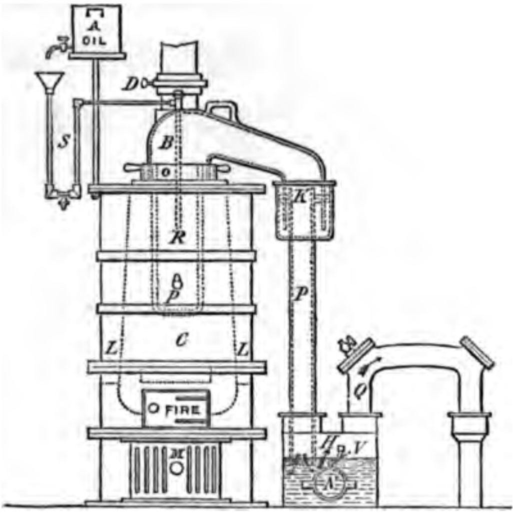

Fig. 292.

For small installations, Mr. Keith has introduced a double retort which is of V-shape in plan and of the ordinary ⌓-shape in section.

Fig. 292 represents the Mansfield producer, in which oil gas may be made from any kind of oil or fat as well as from paraffin oils. The oil or fat in the vessel, A, runs continuously into a siphon pipe, S, where it becomes vaporised, the vapour passing into a retort, R, heated to a cherry-red. The retort is surrounded by a cast-iron casing, C, lined with firebrick, L. The supply of air and the discharge of the products of combustion are regulated by dampers, M D. The oil is not supplied to the siphon, S, until the retort is fully heated, as seen through an opening, *p*. The gases pass through the retort hood, B, and down a stand-pipe, P, to the hydraulic box, H, whence, after being purified from tar, they escape at Q to the gasholder. N is a door through which the tar is withdrawn from the box, and V a safety valve. The hood, B, rests upon two sockets, O K. One of these (K) forms a water seal through which the gas escapes in the event of excessive pressure occurring. The other (O) is filled with lead which melts with the heat, the hood sinking into it, and a gas-tight joint being thus formed. When worked with "intermediate" oil, from 7 to 9½ gallons of oil is used per 1,000 feet of gas, the cost of oil and fuel, with the former at 4½d. per gallon, being about 5s. per 1,000 feet. The temperature of the vessel, A, is sufficiently high to liquefy solid fats.

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[1] Stevenson, *Proc. Inst. Civ. Engineers*, lxxxix.

In the Thwaite plant (Fig. 293) the generator consists of an iron retort enclosed in a slow-combustion chamber, the heating being effected by the combustion of coke. The oil trickles into the retort down a central tube, and the vapour passes up between the tube and the sides of the retort, the permanent gas thus formed being conducted away at the top to a condenser and thence to an oxide of iron purifier.

For the enriching of water gas, the oil gas is frequently produced by passing the water gas with the vapour of the oil through superheaters, as in the Lowe, Springer, and other processes used in the United States and elsewhere. In the six months ended December 31, 1891, the London Gas Light and Coke Company are said to have employed, as an enricher, oil gas equivalent to the gas from 14,631 tons of cannel coal.[1] The accounts of this company show that in the six months ended December 31, 1894, no less than 511,761,000 cubic feet of oil gas was used by them.[2]

In the Lowe process, as described by Professor Lewes,[3] coke or anthracite is heated to incandescence, in a generator lined with firebrick, by an air blast, the heated products of combustion, as they leave the generator and enter the superheaters, being supplied with more air, which causes the combustion of the carbon monoxide present in the producer gas, and heats up the firebrick "baffles" with which the superheater is filled. When the necessary temperature of the fuel and superheater has been reached, the air blasts are cut off, and steam is blown through the generator, forming water gas, which meets the enriching oil at the top of the first superheater, called the carburettor, and carries the vapours with it through the main superheater, where the "fixing" of the hydrocarbons takes place. The chief advantage of this apparatus is that the enormous superheating space enables a lower

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[1] *Engineer*, 1892, lxxiv., 13.

[2] *Gas World*, Feb. 2, 1895, 125.

[3] *Cantor Lectures*, 1890.

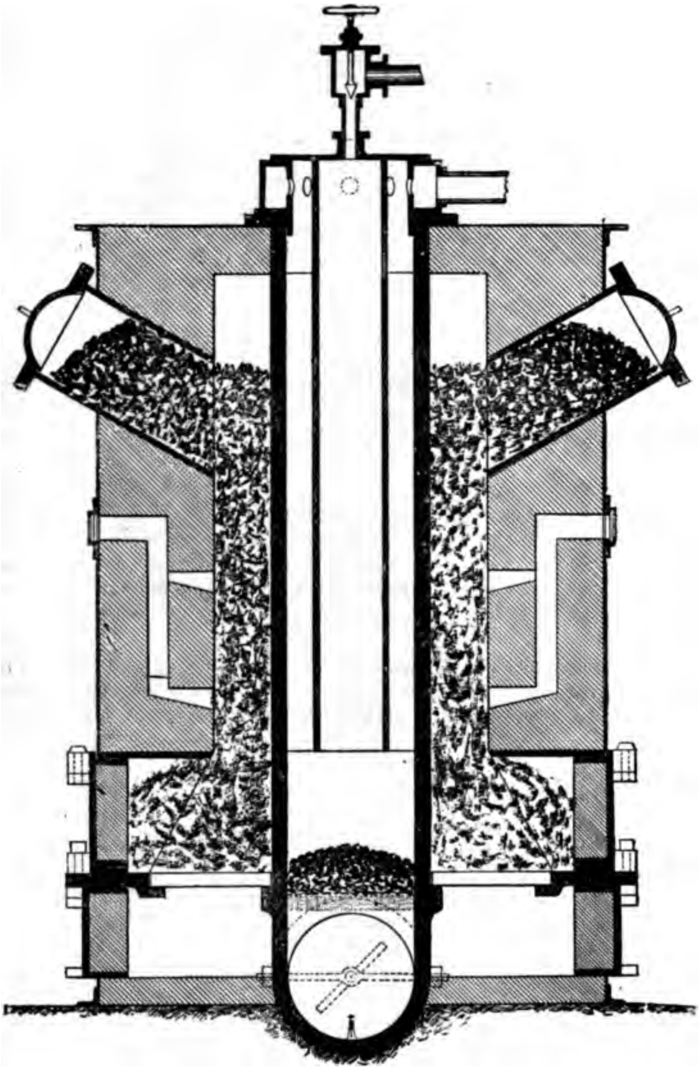

Fig. 293.

temperature to be used for the "fixing." This does away, to a great extent, with the too great breaking down of the hydrocarbons, and consequent deposition of carbon.

In a description of the Lowe process as used at Beckton, Mr. T. Goulden[1] states that there are twelve generators capable of producing

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[1] *Journ. of Gas Lighting*, &c., May 23, 1893, lxi., 939.

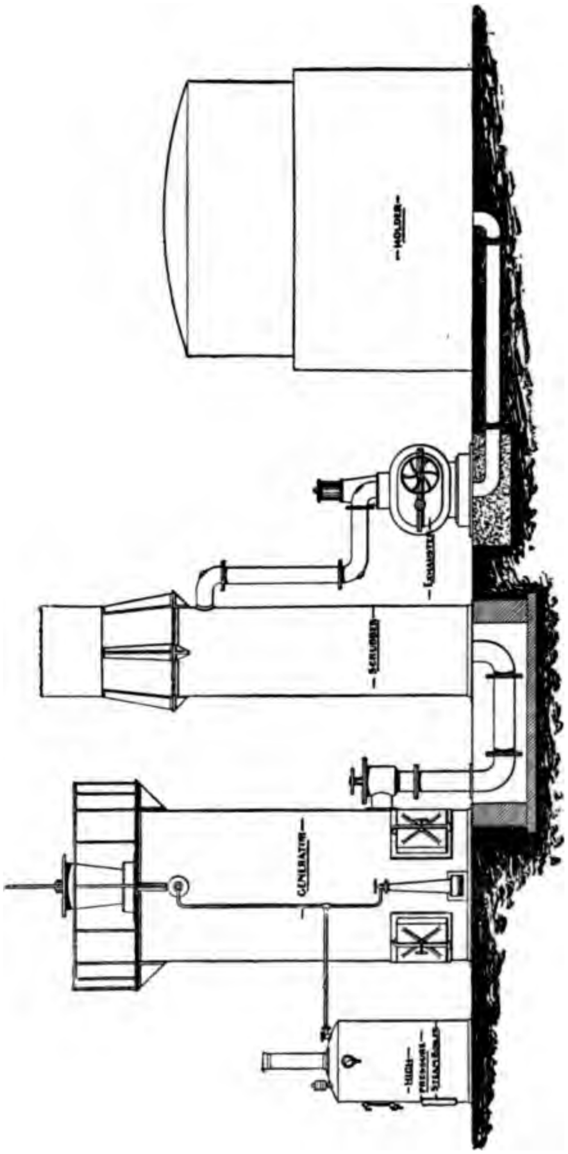

Fig. 294.

6 million cubic feet of carburetted water gas daily, and actually producing about 5 million feet per day. The efficiency of the gas obtained was, at the time of publication, 1,082 candles per gallon of

"Russian distillate" used, and the gas was employed to the extent of about 10 per cent., for enriching ordinary coal gas. The coal gas may be considered to contain 8 per cent. of carbon monoxide, while the mixed gas issued to the consumer contained about 10·5 per cent.

In the Springer process, which differs from the Lowe only in the construction of the apparatus, the superheater is directly above the generator, and there is only one superheating chamber instead of two. The air blast is admitted at the bottom, and the producer gases heat the superheater in the usual way. When the required temperature is reached, the steam is blown in at the top of the generator, and is made to pass through the incandescent fuel, the water gas being led from the bottom of the apparatus to the top, where it enters at the summit of the superheater, meets the oil, and passes down with it through the chamber, the finished gas escaping at the middle of the apparatus.

Although carburetted water gas is still only used to a comparatively small extent in England, and then only for the purpose of enriching coal gas, it is stated that of the 60,000,000,000 cubic feet of illuminating gas made in the United States and Canada daily, two-thirds consists of carburetted water gas.[1] Several of the arrangements in use in America for the production and carburetting of water gas are described by Hempel.[2]

Fig. 294 illustrates an arrangement introduced by Mr. Thwaite, for making enriched producer gas of constant quality, usually of about the same heating power as ordinary coal gas. The figure represents the installation in use at the Southall Gas Works of the Brentford Gas Corporation. There are two producers which are automatically and regularly charged with coke or anthracite, and are used alternately. The products of combustion in one producer are drawn through a flue into the other, in which they are converted by passage through its incandescent fuel, into hydrogen and carbon monoxide. These gases are collected in a separate holder, or are used for diluting the final product. After a proper interval, the direction of the gases is reversed by automatic valves, and after four reversals, the air, which has raised the fuel to incandescence, is shut off, and oil is sprayed in by a steam injector at the upper part of one of the producers. The oil vapour passes with the steam through the incandescent fuel in the other producer, and is there converted into permanent gas in admixture with the water gas produced by the decomposition of the steam by the fuel. When the temperature of the fuel falls too low, the oil is shut off, and the fuel is re-heated by admitting air. Professor Robinson states that of the expenses of working, 95 per cent. is for oil, 3 per cent. for anthracite or coke, and 2 per cent. for labour, and that, taking crude petroleum at 50s. per ton at the works, the cost of gas, equal in lighting and heating power to ordinary London coal gas, would work out at about 1s. 8d. per 1,000 feet. This however, does not include the cost of condensation, purification, &c.

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[1] Goulden, *l.c.*

[2] *Journ. f. Gasbeleuchtung*, xxxvi., 465 and 492.

Messrs. W. Young and A. Bell[1] have introduced a system (generally known as the Peebles process) of manufacturing oil gas, which is now employed at the Galashiels Gas Works. The plant is represented in Fig. 295, which is taken from the *Journal of Gas Lighting*, 1893, p. 265. The retorts used are of cast iron, of cylindrical form, and larger than those employed for making coal gas. They are 9 feet long and 27 inches in internal diameter, and are slightly inclined, as shown. The oil retorts and the ordinary coal retorts, A, are set back to back, and the former are heated at C by the gas from a "semi-producer," which furnishes the heat required for the carbonisation of the coal. The front of each oil retort has a mouthpiece, B, with a circular door and an off-take pipe communicating by pipes, D, with the hydraulic main, E. From the condenser, M, the gas passes to the scrubber, N, above which is a cistern, O, containing the oil used for scrubbing. The compensating and settling tank is shown at F, the oil outlet from the hydraulic main at G, the main oil-feeding pipe at H, the regulating valve and siphon pipe at K, and the fresh-oil supply pipe and ball cock at L. At Galashiels, "blue-oil" of specific gravity 0·885 is used, and the temperature in the retort is from 1,200° to 1,300° F., the inside temperature in the centre of the retort being about 900° to 950° F. The temperature, however, varies with the nature of the oil, and is much higher for blast-furnace oil and coal tar.

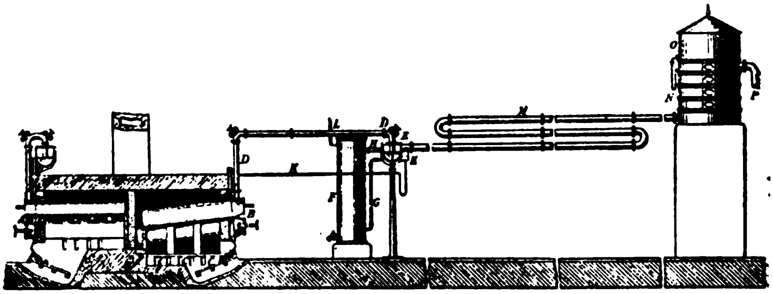

Fig. 295.

The oil is allowed to enter the retort at such a speed that it is not wholly converted into permanent gas, but in part is vaporised only. The arrangement adopted is said to result in a fractional vaporisation of the oil as it passes from end to end of the retort, and in the subjection of the vapours to gradually increasing temperatures. The inflowing oil removes soot, &c., from the gas issuing from the retort. The gas on leaving the scrubber is mixed with the low-quality coal gas at the inlet of the purifiers. The coke from the oil retorts is hard, dense, and almost free from sulphur. The plant is of course applicable for the manufacture of oil gas otherwise than for admixture with coal gas, and the drawing merely shows an arrangement (very different from that figured in the patent specification) well adapted for a gas works.

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[1] Patents No. 12,421, 1892, and No. 12,355, 1893.

The working of this process has been reported upon by Professor Lewes,[1] Mr. F. T. C. Linton,[2] Mr. S. Glover,[3] and Mr. A. Yuill.[4] Professor Lewes states that when used for enriching 18-candle gas obtained from splint coal, the efficiency of the oil gas equals 85 feet of 90-candle gas, or 1,530 candles, per gallon of oil. This, as pointed out by Dr. Stevenson Macadam,[5] is a higher efficiency than can be obtained by burning the oil itself in a first-class lamp, such as Doty's lighthouse lamp. Mr. Linton asserts that this process would produce oil gas cheaper than gas from high-class cannel at the lowest price ever reached, even if the cost of the oil were doubled. Professor Lewes gives the following analysis of the gas :—

	Per cent.
Hydrogen,	16·85
Unsaturated hydrocarbons,	44·83
Ethane,	17·30
Methane,	19·00
Carbon monoxide,	0·00
Carbon dioxide,	0·63
Oxygen,	0·24
Nitrogen,	1·15
	100·00

There was a distinct trace of sulphuretted hydrogen derived from the sulphur in the shale oil from which the gas was obtained. The oil circulating in the apparatus was found, on the examination of samples, to be highly charged with naphthalene, and to contain only small traces of hydrocarbons with low boiling points; but the oil from the trays in the scrubber consisted of the original oil highly charged with benzene and light saturated and unsaturated hydrocarbons boiling between 65° and 140° C., chiefly hexane, heptane, nonane, hexylene and heptylene. "These data point to the fact that, in the retort, the shale oil decomposes in the usual way, yielding saturated and unsaturated hydrocarbons, some gaseous and some vapours of volatile liquids. The contact with the hot sides of the retort causes the splitting up of some of the ethylene into ethane, methane and acetylene, and the latter at once polymerises into benzene and, still further, into naphthalene. Leaving the retort and passing through the condensing coil, the oil dissolves out all the naphthalene from the gas, whilst in the trays of the scrubber the close contact with fresh oil removes the vapours of benzene and anything else which could afterwards undergo condensation. It is this which makes the Young gas so permanent."

Mr. J. F. Tocher[6] gives the result of a number of experiments on the production of oil gas. The following table shows the nature of the products from various oils, the cracking of the oils being carried out in a cylindrical iron retort, 36 inches by 6 inches :—

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[1] *Journ. of Gas Lighting*, &c., June 20, 1893, lxi., 1150.

[2] *Ibid.*, 738.

[3] *Ibid.*, June 5, 1894, lxiv., 1050.

[4] *Ibid.*, lxv., 1894, 234 and 278 ; see also Young and Galloway, *ibid.*, lxv., 1894, 236, 238, and 326.

[5] *Ibid.*, lxii., 12.

[6] *Journ. Soc. Chem. Ind.*, March 31, 1894, 231.

TABLE LXVII.—Products yielded by Various Oils.

	Mineral Naphtha. Sp. gr. 0·730.		Burning Oil. Sp. gr. 0·807.		Mineral Oil. Sp. gr. 0·847.			Mineral Oil. Sp. gr. 0·884.		
Temperature,	600° C.	850° C.	600° C.	850° C.	600° C.	800° C.	1,100° C.	500° C.	600° C.	850° C.
Cubic feet per gallon of oil, .	72	100	75	93	64	82	95	34	59	108
Colour of gas, ...	White.	White.	White.	Brownish-white.	White.	Light brown.	Dark brown.	Light yellow.	Light yellow.	Brown.
Composition of gas—	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
C_nH_m hydrocarbons, . .	31·2	29·8	32·8	43·1	33·7	46·2	21·5	44·7	40·5	35·7
C_nH_{2m+2} hydrocarbons, .	47·6	48·7	57·0	47·2	50·1	39·4	49·2	40·1	48·2	46·3
Hydrogen, ...	17·4	19·1	7·1	7·6	13·7	11·9	28·4	12·7	8·1	16·1
Carbon density of C_nH_m, .	2·67	2·71	3·93	2·92	2·88	2·75	2·41	3·11	2·95	2·79
Hydrogen density, . .	...	...	...	...	4·87	5·22	5·16	5·38	5·54	4·46
Illuminating power— In candles corrected to 5 cub. ft. of gas and 120 grains sperm per hour,	43·5	42·2	48·7	61·4	52·5	64·8	36·2	63·8	57·7	49·0
Candles per gallon, . . .	626	844	730	1,142	659	1,062	688	434	693	1,058
Pounds sperm per ton, . .	3,292	4,437	3,482	5,447	2,987	4,815	3,119	1,885	2,974	4,596
Enriching value, pounds sperm,	...	...	...	6 per cent. mixture gave 10,174. Enrichment figure = 115.	...	5 per cent. mixture gave 6,872. Enrichment figure = 96·5.	...	...	...	...
Percentage of residuals, . .	11·4	5·1	21·4	7·5	28·5	12·2	18	62·3	41·5	9·4

TABLE LXVIII.—PRODUCTS YIELDED BY VARIOUS OILS.

	Octane, C_8H_{18}. Boiling point, 122° C.		Decane, $C_{10}H_{22}$. Boiling point, 156·5° C.		Turpentine Oil, $C_{10}H_{16}$. Boiling point, 154°-158° C.	Naphtha, 0·730.	Mineral Oil, 0·884.	
Temperature,	550° C.	800° C.	550° C.	800° C.	800° C.	850° C.	500° C.	850° C.
Yield, ...	18 litres per 100 c.c.	42 litres per 100 c.c.	24·6 litres per 100 c.c.	47·5 litres per 100 c.c.	63·3 c.f. per gall.	100 c.f.	34 c.f.	0·108 c.f.
Colour of gas, . . .	White.	White.	White.	White.	White.	White.	Light yellow.	Brown.
Composition of gas— C_nH_m hydrocarbon, .	23·5	12·3	27·4	13·4	19·1	29·8	44·7	35·7
C_nH_{2m+2} hydrocarbon, .	39·4	35·4	36·0	50·1	54·1	48·7	40·1	46·3
Hydrogen, . . .	35·7	52·8	35·7	36·5	26·8	19·1	12·7	16·1
Ethylene equivalent of C_nH_m, . . .	30·0	11·7	32·1	14·2	30·4	35·2	69·5	49·8
Carbon density, . .	2·56	1·91	2·35	2·12	3·20	2·71	3·11	2·79
Illuminating power, in candles per 5 cubic feet,	18·0	...	20·2	12·0	39·1	42·2	63·8	49·0
Residuals, per cent., . .	22·0	A few drops.	50·0 Composed almost entirely of unchanged decane.	None.	16·6	5·1	62·3	9·4

TABLE LXIX.—OIL GAS IN VARIOUS PROPORTIONS OF COAL GAS.

Percentages.		Candles observed.	Rate.		Candle Power at 5 cubic feet per hour and 120 grains Sperm.	Theoretical Figure for the Mixture, calculated from Observed Candle-power of separate Gases. $p_3 - \frac{(x \times P_1) + (y \times P_2)}{100}$	Enrichment Figure found = Intrinsic Illuminating Value of Oil Gas. $p_1 = \frac{y(P_3 - P_2)}{x} + P_3$	Increase in Candle-power per cent. of Oil Gas taken. $C_1 = \frac{P_3 - P_2}{x}$.
Oil Gas.	Coal Gas.		Gas per hour.	Grains Sperm per hour.				
100	...	11·22	2·08	117	52·5	...	...	...
...	100	10·40	5·00	115	19·5	...	...	...
75	25	10·25	2·30	125	46·4	44·2	55·3	0·36
60	40	10·84	2·55	121	42·9	39·3	58·5	0·39
40	60	7·40	2·12	118	34·2	32·7	56·2	0·37
20	80	9·32	3·02	117	29·9	28·1	71·5	0·52
13	87	11·94	4·42	122	27·4	23·00	77·8	0·62
100	...	...	...	...	57·7	...	...	...
...	100	...	...	...	20·5	...	...	...
5	95	12·4	5·00	118	24·3	22·3	96·5	0·76
100	...	...	...	...	61·4	...	...	...
...	100	...	...	...	20·5	...	...	...
6	94	10·5	4·01	121	26·2	22·9	115	0·95

These results indicate that the temperature which produces gas of the highest illuminating power, lies between 800° and 850° C., which is said to be much lower than that employed in the Pintsch and Keith oil gas retorts, and that the higher temperatures tend to produce free hydrogen at the expense of the heavier, light-producing hydrocarbons. The results given in Table LXVIII. are also of interest in this connection. The experiments on octane and decane were performed in a cylindrical iron retort 8 inches long and 3 inches in diameter, while the turpentine was decomposed in an iron retort 36 inches long and 6 inches in diameter.

Mr. Tocher observes that the larger proportion of unsaturated hydrocarbons is found in the gas produced from oils mainly composed of the higher members of the olefine series, and states that the Scotch mineral oils must, therefore, be the best for manufacturing oil gas, and Russian oil better than American.

Table LXIX. shows the results obtained by him in the enriching of coal gas with various proportions of oil gas.

A process for the manufacture of illuminating gas recently introduced by Professor Vivian B. Lewes[1] consists in the production of a mixture of hydrogen, oil gas, and water gas in a single operation, the hydrogen being formed by the action of steam on incandescent iron, and the water gas and oil gas by the action of steam on incandescent coke, and the simultaneous "cracking" of oil injected into the fuel.

The apparatus employed consists of a generator divided into three compartments, the inner of which is filled with coke, while the two outer ones are filled with iron. The coke is heated to incandescence by an air blast, the carbon monoxide and nitrogen which form the products of combustion being passed for the first four or five minutes of each "blow" down through iron chambers to reduce the oxide of iron, produced by the previous action of steam, to the metallic state. When the fuel and iron are sufficiently heated, the blast is shut off and superheated steam is admitted to the bottom of the iron chambers in which it forms hydrogen gas and iron oxide. At the same time, crude oil is injected by means of superheated steam into the centre of the fuel, whereby a mixture of water gas and the products of the cracking of the oil is obtained. Another jet of superheated steam, admitted below the oil injectors, causes an "uprush" of water gas which carries away the oil gas, thus preventing over-cracking, and at the same time arrests any flow of the oil downwards through the fuel. The hydrogen, oil gas, and water gas mix at the top of the generator and pass away to coolers and purifiers. When the temperature falls below that necessary for the rapid production of gas, and the proportion of carbon dioxide rises, the valves leading to the gas mains are closed, the fuel is reheated, and the iron oxide reduced as already described. It has been found advisable to place an asbestos cloth over the surface of the iron to arrest the fine dust which is carried over from the fuel, and it is further found that if the temperature be allowed to become too high, the oxide of iron fuses and thus becomes of inferior power.

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[1] *Journ. of Gas Lighting*, &c., lxi. (1893), 871, and lxii. (1893), 632.

The apparatus is said to be very compact, a generator for producing 250,000 cubic feet of gas daily, only occupying a space of 18 feet by 7 feet, and having a height of 10 feet. The initial cost is also stated to be low. The gas can be made of about the same specific gravity as ordinary coal gas. According to the experiments of Dr. L. T. Thorne, 3·75 gallons of oil is required for the production of 1,000 cubic feet of 20·7 candle gas. These figures, when compared with those given by Messrs. Paddon and Goulden as the result of their experiments with the Lowe gas process, show a saving of 22·2 per cent., and Professor Lewes states that recent results indicate an economy of over 40 per cent.

In a paper recently published by Dr. Paul Dvorkovitch on the "Gasification of coal and liquid hydrocarbons"[1] and in the discussion which followed it, the question as to the relative merits of processes in which by-products of value are produced and those by which illuminating gas only is obtained, was brought forward. Three oils were experimented upon—(A) A "solar oil" of specific gravity 0·8625, flashing at 53° C., and yielding on distillation 10 per cent. of distillate at temperatures up to 200° C., 20 per cent. between 200° and 250° C., 30 per cent. between 250° and 300° C., and 7 per cent. between 300° and 350° C. The specific gravity of the mixed distillates was 0·8442, that of the residue being 0·8927. (B) A "special solar oil" having a specific gravity of 0·8852 and a flashing point of 120° C. It yielded no distillate up to 350° C. (C) A "special distillate" of specific gravity 0·8991 and flashing point 115° C., which yielded 2 per cent. of distillate at temperatures up to 200° C., 7 per cent. between 200° and 250° C., 10 per cent. between 250° and 300° C., and 9 per cent. between 300° and 350° C. The specific gravity of the mixed distillates was 0·8607 and that of the residue 0·9097.

These oils were separately gasified in an apparatus consisting of two iron pipes arranged horizontally one above the other and connected at one end. The other end of the uppermost pipe was carried up vertically about 8 inches and fitted with a funnel and stop-cock, while the other end of the lower pipe was connected with a condenser and gasholder. The following table gives the results of the experiments:—

	Temperature of breaking up.	Cubic feet of Gas per ton.	Candle Power.	Candles per gallon of Oil.	Per cent. of Residuals.	Specific gravity of Residuals.
	°F.					
A. "Solar oil," . .	1,600	126·5	22·8	576	32·0	0·9834
A. "Solar oil," . .	1,300	71·4	46·6	665	37·5	0·9266
B. "Special solar oil,"	1,300	69·8	53·7	749	37·5	0·9464
C. "Special distillate,"	1,300	69·0	60·3	832	38·0	0·9670

It will be observed that, although the higher temperature produces an enhanced yield of gas, the illuminating power and the total illuminating value measured in candles per gallon of oil, are much reduced, the proportion of residuals being also diminished. A still higher temperature further increases this difference. The residuals from the "special distillate" (the heaviest oil experimented upon) were much superior to those from the "solar oil" A, even when the latter oil was gasified at the lower temperature, both as regards quantity and the amount of benzene present. That from the latter oil contained a large proportion of light spirit other than benzene, but the residuals from the "special distillate" consisted mainly of benzene with very little of the light spirit. At the present price of benzene, this would be a matter of considerable importance.

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[1] *Journ. Soc. Chem. Ind.*, 1893, xii., 403.

Professor Lewes, however, expressed the opinion, when discussing these results, that the demand for benzene is not such as to justify the anticipation that the present price could be maintained if such a process were largely carried out, and that it is preferable to obtain a higher yield of gas at the expense of the residuals.

A process, known as the *hydro-oxy oil gas* process, was patented in 1890 by Mr. E. Tatham, and has since been tested experimentally in Salisbury Square, London, as well as at the Huddersfield Corporation Gas Works. The process (which has for its object the increase of the illuminating power of oil gas by the addition of oxygen) has been reported upon by Dr. Leonard T. Thorne, and has been described in the *Journal of Gas Lighting*, &c.[1]

It has been found that oil gas can be burned in the ordinary way with facility and safety after admixture with 30 per cent. of oxygen—*i.e.*, with double the quantity ever employed in the Tatham process—and that the richest oil gas which can be made by retorting oil, can be burned with a smokeless flame by means of an ordinary union-jet burner, after admixture with from 15 to 20 per cent. of oxygen. If more than 20 per cent. of oxygen be used, the flame is found to be whiter but to possess a lower illuminating power. In his fourth Cantor Lecture at the Society of Arts, December 12, 1892, Professor Lewes says—"If a rich oil gas be taken and a certain percentage of oxygen be added to it, this helps the combustion, and we can burn the mixture at a larger burner than could be used without the oxygen, and in this way, by decreasing the cooling influence of the smaller burner, we get an increase of luminosity which will, in some cases, amount to as much as 25 per cent." Shortly afterwards, Mr. Herring reported that the addition of 5·09 per cent. of hydro-oxy oil gas to a poor coal gas of 12·56 candle-power, increased its illuminating power by 4·09 per cent.

It is proposed to store the hydro-oxy oil gas and add it to the coal gas, as required, after purification, but in the experimental plant at Huddersfield, the enriching gas was passed direct into the foul gas main. The oil-gas plant employed, consists of a bench of fifteen circular iron retorts 5 feet 6 inches long between the walls. The retorts are arranged in 4 tiers nearly horizontally, but with a slight fall to the back. The twelve upper retorts are 8 inches in diameter. The lower tier consists of three retorts which are 10 inches in diameter. These, being nearest the fire, are used only for retorting the residuum from the other twelve, and this process is carried on to coking, only a little tar being obtained. The oil is run into the retorts through central 2-inch pipes inserted through the lids in front and extending nearly to the back. The supply is controlled by a regulator, consisting of a syphon fitted with a float, and is thus automatically stopped in case the retorts happen to choke, or there is, from any other cause, an excess of back pressure. The retorts in which the fresh oil is gasified, are maintained at a dull red heat, and the gas is taken off at a "canary" colour, but the residuum is decomposed at a higher temperature.

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[1] March 25, 1890; October 3 and 10, 1893; and June 5, 1894, 1054 (Herring).

The oxygen, which is made by Valon's modification of Brin's process, is introduced into the oil-gas main while the gas is still warm, the proportion of 15 per cent. being maintained by drawing it through a meter driven by the oil-gas meter. The effect of the addition of the oxygen is shown by the following account of a six days' test conducted by Dr. Thorne :—4 tons 8 cwts. of "solar distillate," costing £3, 5s. per ton, was retorted, and the 85,000 cubic feet of gas obtained was mixed with 15,000 cubic feet of oxygen, the hydro-oxy gas thus produced being mixed with 1,300,000 cubic feet of coal gas of 18 candle-power. The illuminating value of the mixture was 24 candles, which gives an enriching value for the hydro-oxy gas of 100 candles, and a "duty" of 1,700 candles per gallon of oil. Mr. Herring states that the cost of the oxygen amounts to upwards of 14 per cent. of the cost of enrichment, but that the difference in favour of the hydro-oxy oil gas over ordinary oil gas for enrichment purposes amounts, according to his results, to 49 per cent. These figures indicate a high efficiency for the Tatham process, although the amount of oxygen used only amounted to a little over 1 per cent.; but Professor Lewes, in the lecture already referred to, says—"If we now take this oxy-oil gas and attempt to enrich a poor coal gas by mixing the two together, we at once find that the mixture has a *lower* illuminating value than if oil gas without oxygen had been used for enrichment." It is stated that, on storage over water in small gas-holders, coal gas of 15·32 candle-power lost 2·38 candle-power in six days, coal gas enriched by cannel lost 4·50 candles, and coal gas enriched by the addition of 5 per cent. of hydro-oxy gas lost only 1·51 candle.[1]

NATURAL GAS.

Although natural gas is used to a considerable extent as a source of light in the United States, by far the larger proportion is employed as fuel. It was estimated that in 1889, in addition to a great number of factories, no less than 500,000 domestic heating and cooking fires were supplied with it.[1] The total amount of natural gas used in the United States in that year was equivalent to a quantity of coal valued at over 21 million dollars.

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[1] Further information on the production and use of oil gas will be found in the following publications:—*Journal of Gas Lighting;* Robinson (Cantor Lectures, 1892); Ayres (*Proc. Inst. Civ. Engineers*, xciii., 298-363); Donkin (*Gas, Oil, and Air Engines*); Armstrong (*Journ. Soc. Chem. Ind.*, 1884, 462, and Thorpe's *Dictionary of Applied Chemistry*); Lewes (Cantor Lectures, 1890). The water-gas plant at the Belfast gas works was described by J. Stelfox before the Incorporated Gas Institute in 1894.

PETROLEUM AS FUEL.

Crude petroleum and petroleum residuum are used to a very large extent as fuel, mainly, of course, in countries where solid fuel is comparatively costly. In America, the crude oil produced in Ohio is thus employed, while in Russia, the "astatki" or residuum obtained by the refiners is in such demand for use as fuel, that it occupies a most important position. Other heavy oils, such as blast-furnace oil and tar oils, are similarly employed, but these do not come within the scope of this work.

Liquid fuel is largely applied in metallurgical operations, and has replaced coal in many glass works and other industrial establishments. It has also been found available for domestic use, but the principal application is for steam raising.[2]

TABLE LXX.—Oil Fuel.

Locality.	Fuel.	Sp. Gr. at 0° C.	Chemical Composition.			Heating Power.	
			Carbon.	Hydrogen.	Oxygen.	Actual Calorimetric (lb. C. Units).	Calculated (lb. C. Heat Units).
Russian, . .	Petroleum refuse.	0·928	87·1	11·7	1·2	...	11,018
,, . .	Astatki.	0·9	84·94	13·96	1·2	10,340	11,626
Caucasian, . .	Heavy crude.	0·938	86·6	12·3	1·1	10,800	11,200
,, (Novorossisk),	,,	...	84·9	11·63	1·458	10,328	...
Pennsylvanian, .	,,	0·886	84·9	13·7	1·4	...	10,672
American, . .	,,	...	86·894	13·107	...	10,912	...
,, . .	Refined.	...	85·491	14·216	0·293	11,045	...
,, . .	Double refined.	...	80·583	15·101	4·316	11,086	...
,, . .	Crude refined.	...	83·012	13·889	3·099	11,094	...
,, . .	Solid residuum.	...	97·855	0·489	1·196	8,057	...
Scotch, . .	Blast-furnace oil.	0·920	83·64	10·59	9·458	10,328	...

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[1] Weeks, *Eleventh Census Report*, 521.

[2] The use of liquid fuel has been described by Aydon (*Proc. Inst. Civ. Engineers*, 1878, lii., 177); Urquhart (*Proc. Inst. Mech. Engineers*, 1884, 1888, and 1889); Mills and Rowan (*Fuel and its Applications*, Churchill, 1889); Veith (*Das Erdöl*, 1892); Robinson (*Journ. Soc. Arts*, April 29, 1891, and Cantor Lectures, 1892); and the author (*Journ. Soc. Chem. Ind.*, iv., 70, and Cantor Lectures, 1886).

A tabular statement of the calorific value of liquid fuel will be found in the section dealing with the chemical and physical properties of petroleum, and in Table LXX., extracted from Robinson's Cantor Lectures, additional information as to the thermal efficiency of various fuel oils is given.

Dr. Sadler, of Middlesbrough, finds that 1 lb. of creosote oil, when used as fuel in a steam boiler, converts 13 lbs. of water into steam at 50 lbs. pressure, the water being supplied at 212° F. Allowing for the steam used in injecting the oil, it may be taken that 1 lb. of creosote oil will evaporate 12·35 lbs. of water under the conditions named. Under similar conditions, 1 lb. of the best Durham steam coal evaporated 8 lbs. of water, and Dr. Sadler states that experience proves 1 ton of oil to be economically equal to 2 tons of coal, allowing for the saving in cost of stoking and other incidental expenses.

The highest published figures for the calorific value of liquid fuel are those given by Admiral Selwyn and Mr. E. N. Henwood. The former stated that in a test made at Messrs. Griffith's factory, Victoria Park, London, a Cornish boiler, having a firebrick combustion chamber built inside the flue, indicated an evaporative power of as much as 46 lbs. of water per pound of oil consumed. Mr. Henwood, in tests made with the boilers of the S.S. "Ryde" of 120 tons and about 100 H.P., found an efficiency as high as 41 lbs. of water evaporated per pound of oil.

Referring to these and other results in which a thermal efficiency exceeding the theoretical value, as calculated from the composition of the oil, is indicated, Messrs. Mills and Rowan[1] make the following observations:—

"The wide variety in, or the intermittent character of, the results obtained by the different methods of using liquid fuel—and even by the same method under different circumstances—is due to imperfections in the apparatus used, and to want of experience in the best method of treating the fuel. Admiral Selwyn explained the high evaporative rates obtained by him by assuming that the hydrogen of the steam used in his injectors is burned; and Mr. Henwood, following in his steps, has claimed for his apparatus that the oil and steam are so proportioned that the hydrogen is fully utilised in the same way in his furnaces. But, inasmuch as, in the dissociation of the hydrogen and oxygen composing steam, an amount of heat is absorbed and becomes latent, which is the same as that developed when the hydrogen becomes burnt, and again combines with oxygen to form water, it is very improbable that this view affords an explanation of the results obtained. On the other hand, those who have rejected Admiral Selwyn's view have not given proper weight to several considerations which belong to this subject.

"The estimates made of the calorific value of liquid fuels from their elementary chemical analysis, are usually based upon the amount of carbon contained in them *as if it were solid carbon* and *to be burned as such*. It is, however, beginning to be understood that, even in estimating the calorific value of coal, some alteration is required in this respect, because part of the carbon in it (probably all) does not exist as such in the solid state. In liquid fuels, it is certain that none of it exists in that state, and hence weight must be allowed to the argument advanced years ago by Aydon. Speaking of liquid fuel, he said—'Here was a fuel naturally prepared the first stage towards gasification, as to effect the same result artificially, 6,000 or more heat units would have to be expended, which heat would become latent and so be lost as useful work. Now, these 6,000 heat units added to 15,000 heat units derived from converting or burning carbon into carbonic acid, would give 21,000 heat units, which the late Professor Rankine stated to be the amount due to gaseous carbon.' Aydon then applied this estimate to the case of American petroleum, and to the creasote or dead oil which he had used at Woolwich. Taking petroleum of the composition, carbon 86, hydrogen 14, if the value for gaseous carbon were employed, it would give this a calorific value of 26·887 lbs. of water per pound of oil. The dead oil as analysed by Professor Church contained:—

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[1] *Fuel and its applications*, 1889.

	Per cent.
Carbon, ...	86·48
Hydrogen, ...	7·06
Oxygen, &c., ...	6·46
	100·00

"Estimating its calorific power as if its carbon were solid, it would give 17·50 lbs. water per pound of oil, whilst on the basis of gaseous carbon, it would give 22·18 lbs.

"In addition to this point, that the physical state of liquid fuel represents so much latent heat, we have to remember that the carbon which it contains is also combined with hydrogen in hydrocarbons of some kind. These compounds of carbon are very easily dissociated by heat, especially in presence of steam of high temperature, and the result of this action is the formation of gaseous hydrocarbons which have a high calorific power. There is reason to believe that these reactions are accomplished with the expenditure of a moderate amount of 'work' in the shape of heat. The temperature at which steam is dissociated *in the presence of gaseous carbon*, must be less than that which is required with steam and solid carbon, by at least the equivalent of the quantity of heat which becomes latent in gasifying the carbon in order that it may unite with the oxygen of the steam to complete the action $H_2O + C = H_2 + CO$. When the steam is thus decomposed, there is nascent hydrogen in contact with carbon in the gaseous form in some of the heavier hydrocarbons, and there is thus present the opportunity for the formation of those gaseous hydrocarbons which are desired and which ignite at a higher temperature. The oxygen of the decomposed steam may either unite with part of the carbon to form carbonic oxide, or, if left uncombined in the primary reactions, it is ready to support combustion subsequently, and this it does, as is well known, with vigour.

"For the proper carrying out of these reactions certain conditions are necessary. The suitable temperature for the various reactions must be maintained, with sufficient time to enable them to be completed before the application of the heat of combustion is required (that is, before heat is abstracted by the requirements of the furnace). There must also be a proper relation between the steam and oil, whilst the air for combustion should be carried to another point in the furnace and not admitted with the steam and oil. In fact, full consideration of the matter points to some method of primary gasification of the oil with steam before combustion with air, as the most likely to yield the highest results in constant work."

For generating steam in stationary boilers, Mr. Ludwig Nobel suggested the employment of a very simple system, the burner consisting of a series of shallow troughs arranged in superimposed series at the door of the furnace in such a manner that the liquid fuel supplied to the top receptacle overflows into the one beneath it, and thus travels downwards through the whole series. The troughs are separated sufficiently to admit of the entrance of a current of air which sweeps over the surface of the burning oil and carries the flames into the furnace. It has been found that 1 lb. of astatki, when thus burned, evaporated 14·5 lbs. of water in a steam boiler, while it only evaporated 12 lbs. when consumed in a spray burner, and that coal evaporated only 7 to 8 lbs. of water per pound of fuel, in the same boiler.

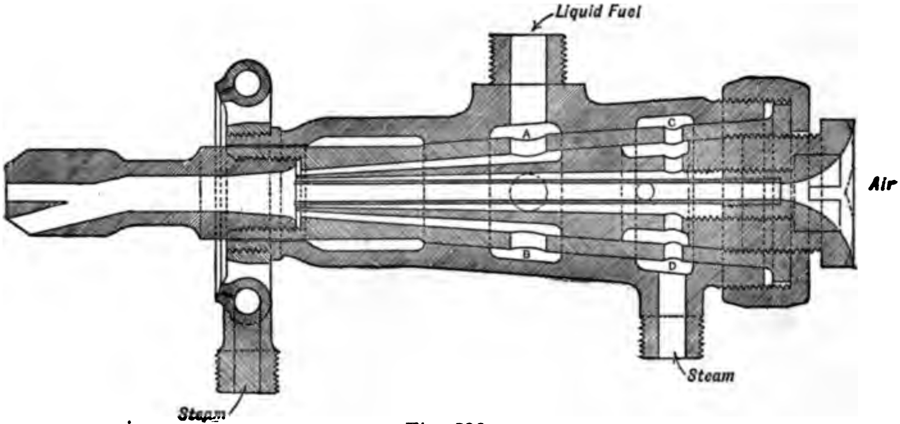

Fig. 296.

It is, however, more common and convenient to burn the oil by means of an injector, the oil being thus driven by a jet of steam, or in some cases, of compressed air, into the combustion chamber in the form of spray, together with the amount of air necessary for its combustion. Such a system was patented as early as 1865-7 by Aydon, Wise, and Field. In 1868, Donald of Glasgow patented a similar arrangement.

Figs. 296 to 298 represent the method of burning liquid fuel invented by Mr. James Holden, and employed on certain locomotives on the Great Eastern Railway, on the Tralee and Dingle Railway in Ireland, and on the steam ferry boat, Middlesex, on the Thames. The injector (Fig. 296) is so constructed that the oil enters at the top and flows down to an annular passage, A B. The main steam supply enters at C D and passes to the nozzle through the annular space between the central air-tube and the passage extending from the oil space, A B, to the nozzle. The steam thus draws in the oil, together with the necessary amount of air, and breaks up the oil into a spray. The oil is further atomised

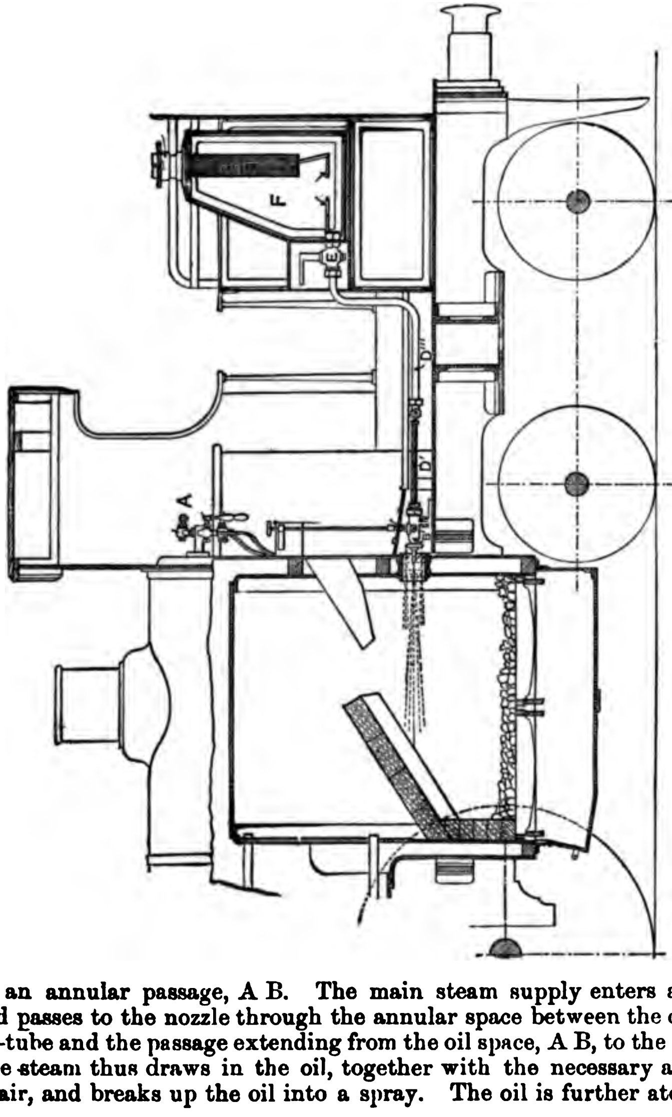

Fig. 297.

by an independent steam supply passing through a hollow ring which is pierced with holes in such a manner that the issuing jets of steam converge towards the nozzle and strike across the current of partly sprayed oil. This auxiliary steam supply also serves the important

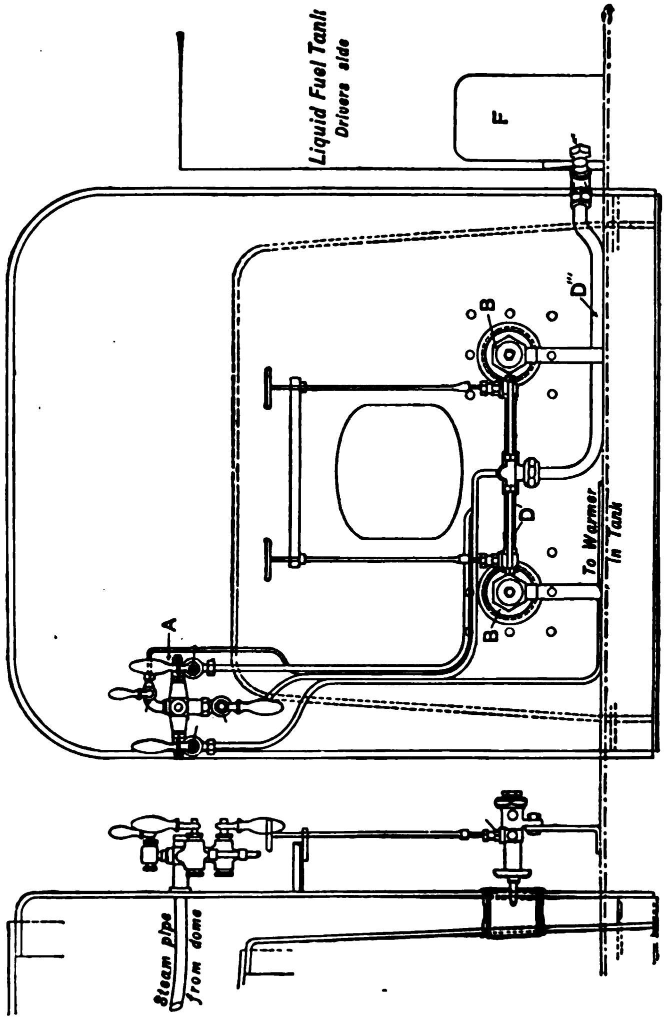

Fig. 298.

purpose of breaking up the main jet, so that the flame has more of a flat lambent nature than of a blowpipe character. Superheated steam is used in all cases. In a more recent modification, fitted to some locomotives, the main steam jet is so arranged as to form an air-injector, and the air-tube is connected by a flexible hose with the vacuum brake.

The oil flows from a tank, F (Figs. 297 and 298), through a pipe, D‴ D′, into the injector, B, and the steam is supplied at A. A steam coil is employed to keep the oil fluid in cold weather. The jet plays upon an inclined firebrick bridge, and the bars of the grate are covered with a thin layer of coal and cinders mixed with lime. As the coal slowly burns away, it is renewed, so that incandescence is always maintained to ensure complete volatilisation and combustion of the oil.

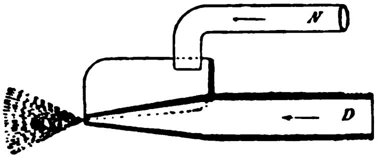

Fig. 299.

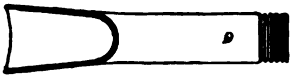

Fig. 300.

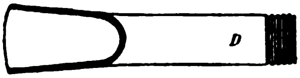

Fig. 301.

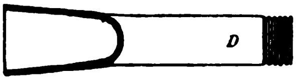

Fig. 302.

Dr. Engler has described[1] a number of fuel burners used in Russia for steam raising and other purposes. Figs. 299 to 302 illustrate a common form in which the astatki enters at N, the size and shape of the flame depending upon the shape of the mouthpiece, D, of the steam pipe.

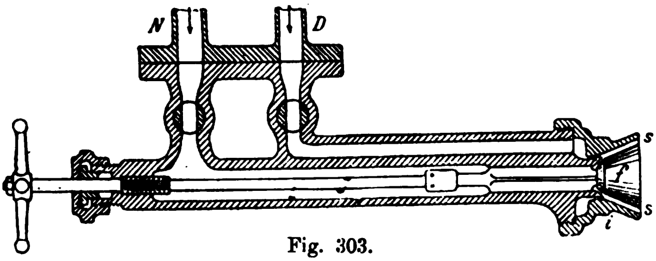

Fig. 303.

In the Brandt burner (Fig. 303), which is largely used, the astatki enters at N, and the steam at D. They meet between the parts *f* and *i*, and a flame is produced at *s*. The regulation is effected by adjusting a cone, *f*. Figs. 304 and 305 show the application of the burner to a Cornish boiler, R being the tank for holding the astatki, and D the steam pipe. Air is admitted to the furnace through orifices in the door, *t*.

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[1] *Dingler's polytech. Journ.*, cclx., 1886, 434.

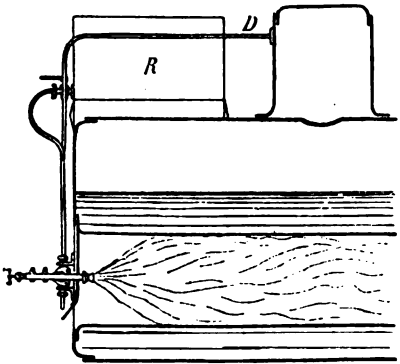


Fig. 304.

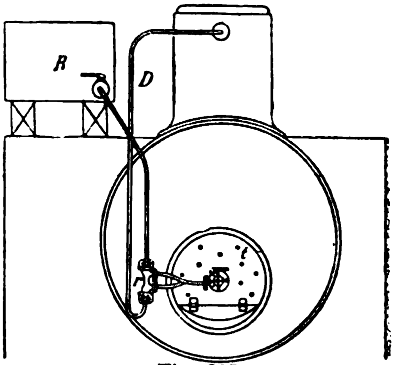
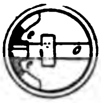


Fig. 305.

Fig. 307.



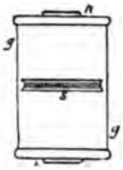


Fig. 306.

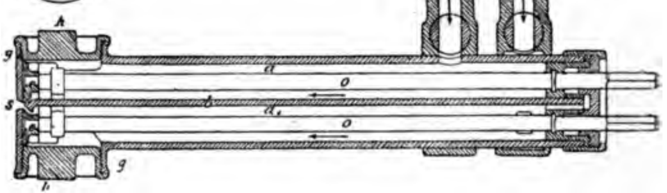


Fig. 308.

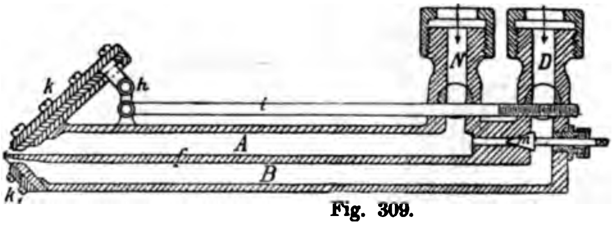


Fig. 309.

The Lenz burner (Figs. 306 to 308) consists of a double tube, *a* a_1, connected with the oil pipe, N, and steam pipe, D. The mixing chamber, *g*, is closed by screw covers, *h*. The eccentric terminals of the rods, *o*, act on slides, *e*, and thus regulate the supply of steam and

Fig. 310.

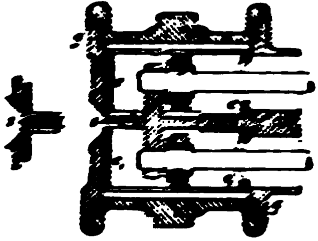
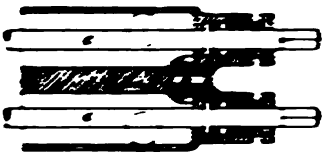


Fig. 311.



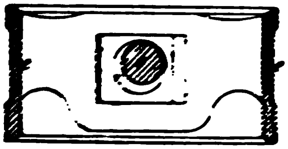


Fig. 312.

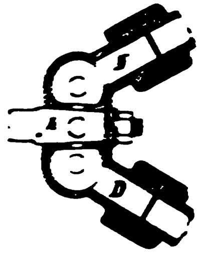


Fig. 313.

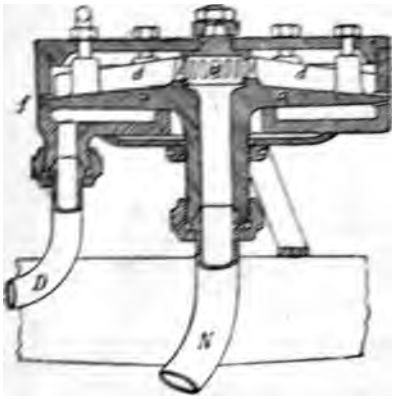


Fig. 314.

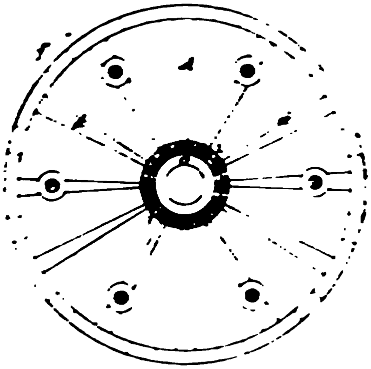


Fig. 315.

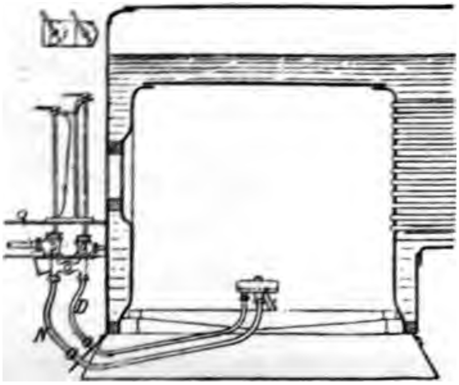


Fig. 316.

astatki. The mouthpiece, *s*, is a horizontal slit extending about half way round the chamber, *g*.

The Saudgreen burner (Fig. 309) is used at the works of Nobel Brothers. N and D are the oil and steam pipes. The mouth, *k*, of the oil chamber, A, is adjustable by links, *h l*, the mouth, k_1, of the steam chamber, B, being fixed. The oil chamber may be cleaned out with steam, on removing the cone, *m*. For locomotive and multitubular boilers, a flame of larger surface is required. An improved Lenz burner for this purpose is represented in Figs. 310 to 313, the difference between this and the ordinary Lenz burner being that here the mouth, *s*, extends all round the chamber, *g*, except where the latter joins the supply pipes. The valves, *e* and e_1, are cylindrical in form and work as shown in Fig. 312. Fig. 313 is a vertical section at the supply pipes, D and N, showing the valve, *h*, for admitting steam for cleansing the oil chamber.

Brandt's locomotive burner (Figs. 314 and 315) has a circular chamber divided by a horizontal disc, *a*. Steam is introduced at D, and the astatki at N, the flow of the latter being regulated by turning a disc, *o*, which opens or closes apertures, *i*. The mouth of the burner is shown at *f*. The same burner is represented in Fig. 316 fixed in the fire-box of a locomotive.

Figs. 317 to 320 exhibit the construction of the appliances adopted by Urquhart for burning astatki on the locomotives on the Grazi-Tsaritzin Railway in South-East Russia. The figures show the radiating chamber of firebrick employed for heating the boiler, and the means adopted for heating the air supply which is drawn in by the exhaust blast of the engine. A sight hole, H, is made in the fire door, and a pointer, D, is arranged on the screw which regulates the oil-supply cock. A pipe, S, supplies steam to a coil in cold weather, in order to prevent solidification of the oil fuel. The oil-supply pipe is shown at P.

Mr. Urquhart states that "with a locomotive in first-class order and in the hands of a skilful driver, 50 tons of petroleum refuse is equal to 100 tons of first-class coal." He estimates the calorific power of petroleum refuse at 19,832 British thermal units.

The Liquid Fuel Engineering Company, of East Cowes, have directed their attention to the construction of water-tube boilers for use with liquid fuel in steam launches. The burner employed with the water-tube boilers manufactured by this company, consists of a generator in which the oil is vaporised, and the burner proper. The latter is a double cone-shaped apparatus fitted with an automatic regulator. The vapour escapes under a slight pressure, and takes with it the proper amount of air to ensure perfect combustion. The oil is forced to the generator by means of an air pump on the engine. In starting the burner, the generator is first warmed by burning methylated spirit beneath it.

The author has on many occasions pointed out the advantages presented by the use of liquid fuel. On shipboard, these are especially marked. Not only can a supply of liquid fuel be taken on board far

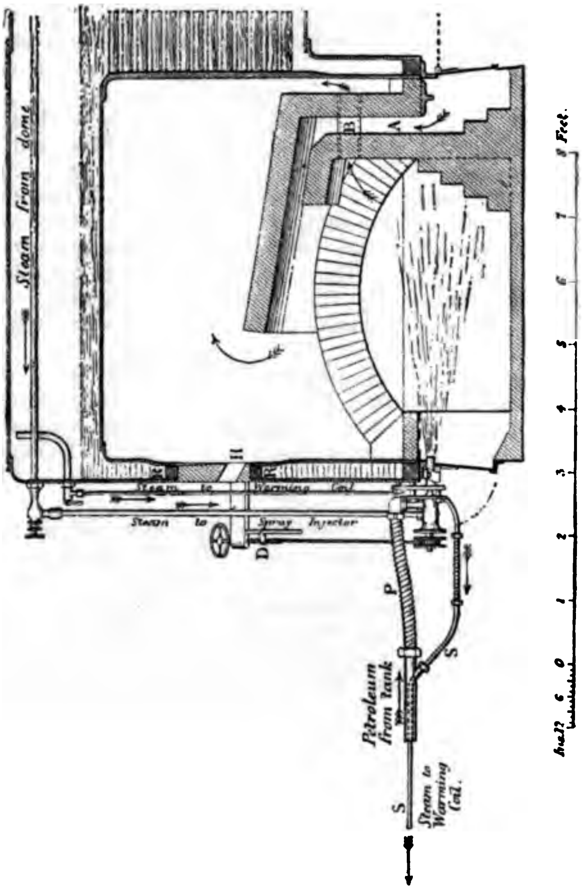


Fig. 318.

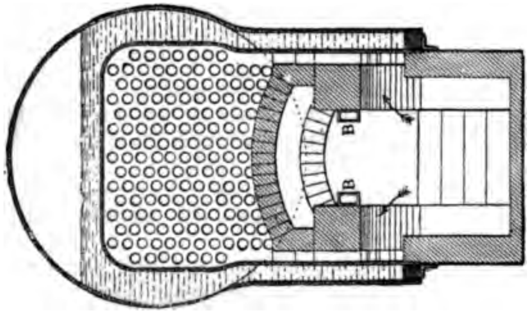


Fig. 317.

more easily, more quickly, and at less cost than a supply of solid fuel, and in the case of a passenger steamer without occasioning the discomfort attendant upon "coaling," but it occupies, for an equal value in steam raising, less than half the space; the vessel can, therefore, either make a far longer voyage without the necessity arising for replenishing the bunkers, or a certain amount of space, which, if coal were used, would be occupied by the fuel, can be devoted to cargo. The labour of stoking and coal trimming, which is most exhausting in a tropical climate, is completely done away with, and there are no ashes and clinkers to be removed. The combustion is smokeless, a point of no small importance in the belligerent marine, no soot or dust is deposited in the boiler tubes, the fire can be instantly extinguished, or as quickly relighted, and is under complete control, waste of steam at the safety valve, on the one hand, or a short supply, on the other, being easily avoided. If the flame should be extinguished in stormy weather, there is no delay in kindling it again, and the risk of scalding is diminished. The oil may be carried in bunkers where coal could not be put, and these may be filled with water as the oil is used, so that the trim of the vessel need not be altered during the voyage, and, if suitable oil is used, there is no danger of explosion or fire, such as attaches to the carriage of coal. The chief practical difficulty hitherto encountered in the use of liquid fuel on shipboard is the provision of the necessary supply of steam for atomising the oil. The steam used in the engines is of course condensed and the water returned to the boilers, but in respect to that which is employed for spraying the

Locomotive Combustion Chambers.

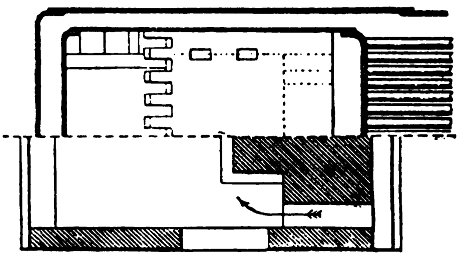


Fig. 319.

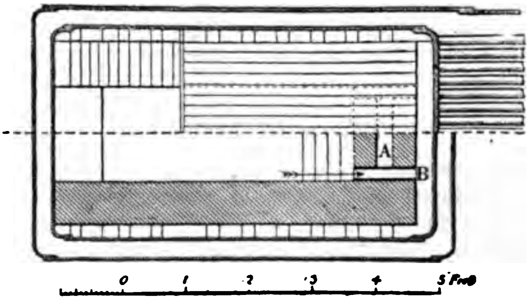


Fig. 320.

oil, an equivalent amount of fresh water must be replaced in the boilers, and to obtain this, it is usually necessary to have an independent distilling apparatus.

It will be apparent that many of the advantages which have been pointed out, attach to the substitution of liquid fuel for coal on locomotives and in stationary boilers. At electric generating stations in large cities, where the delivery and storage of coal and the removal of ashes are not easy, and where in consequence of fog, there may be a sudden and unexpected demand for steam, it would appear to be exceptionally desirable to employ liquid fuel, and there can be but little doubt that, as adequate supplies of suitable oil become available for the purpose, this description of heating agent will be more largely employed.

Oil fuel is also largely used in furnace work. In a method patented in 1883 (No. 1,157) by Mr. J. Riley, for application to regenerative furnaces, the oil is supplied from a tank through a stopcock, to a series of nozzles which are automatically turned to project the oil into either side of the furnace according to which of the regenerators is in action. A method of burning oil in open trays for furnaces in which iron and steel are melted in an open hearth or in crucibles, has been introduced by Nordenfelt.[1]

In the "Eames" process, introduced for the purpose of melting down scrap iron and rolling the product into boiler plates, the oil runs downwards over a series of shelves projecting alternately from opposite sides of a cast-iron generator, and in passing from shelf to shelf, is gasified by a slow current of highly superheated steam. The mixture of vapour and steam passes into a "mixing-chamber," occupying the position of the former fire-space, where it meets the air blast, and is driven through an opening in the furnace bridge-wall and over the furnace bed.

PETROLEUM ENGINES.

As already pointed out at the beginning of this section, petroleum products are employed as a source of power in motors of the gas-engine type, and in one form of motor, petroleum spirit is used similarly to steam. The use of oil gas and of air gas, instead of coal gas, in ordinary gas engines, has also been referred to.

With the earlier forms of petroleum engines, it was necessary to employ mineral spirit, but with the modern types, ordinary kerosene, and oils of even higher boiling points, may be used.

Oil engines have been divided into three classes on the basis of differences in the methods of treatment of the oil in preparing the charge. In the *first*, of which an example is found in the Priestman oil engine, the oil is sprayed and converted into vapour, which is mixed with the proper proportion of air, in the cylinder, where it is compressed and fired, the action being similar to that of the Otto gas engine. In the *second*, exemplified in the Hornsby-Akroyd engine, the oil is injected into a hot "cartridge" at the end of the cylinder, where it is vaporised and mixed with air compressed into this hot combustion chamber. In the *third* class, there is a vaporiser or gas generator in which a small quantity of oil is converted into oil gas and vapour. The gas and vapour are drawn into the cylinder and mixed with air, the mixture being then compressed and exploded. This type of engine includes the Trusty, Crossley, and Capitaine engines.

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[1] Patent No. 11,543, 1884.

The following description of typical oil engines is mainly derived from the work of Mr. Bryan Donkin[1]:—

The employment of petroleum spirit in engines was proposed soon after the introduction of the gas engine, and in 1873, the Hock engine for use with benzoline was patented in Vienna. The ignition of the charge was affected in the following manner:—A small air pump, driven from the crank shaft, forced a current of air at each stroke into a small receiver filled with benzoline. The air became charged with benzoline, and a stream was directed through a nozzle against a permanent burner, placed close to an opening at the back of the cylinder. The benzoline ignited at the flame, a flap covering the admission valve was lifted by the suction of the in-stroke, the flame drawn in, and the mixture in the cylinder ignited. The permanent burner was fed with petroleum spirit from the same receiver. The mixture in the cylinder was produced after the motor-piston passed the inner dead-point, by the simultaneous admission of benzoline and of air which atomised it. The whole cycle of operations occurred during a single forward and return stroke, the latter discharging the products of combustion.

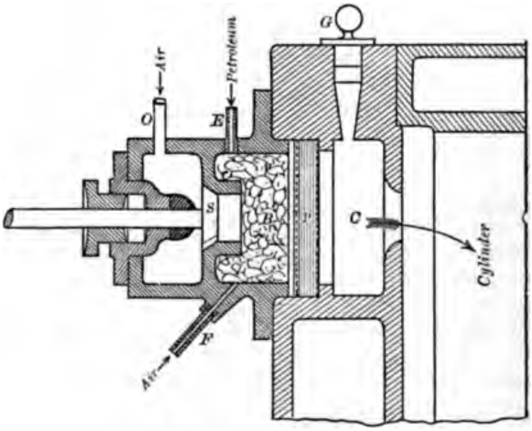

Fig. 321.

The Brayton engine, patented in the United States in 1872, was the first in which ordinary kerosene was employed, and was known as the "Ready-motor." It was the first in which the principle of combustion at constant *pressure* was adopted, and was also the first in which the oil was sprayed. In this engine, air and petroleum are both admitted at high pressure at F and E (Fig. 321) into a carburettor placed at the top of the motor cylinder and filled with felt,

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[1] *Gas, Oil, and Air Engines*, 1894.

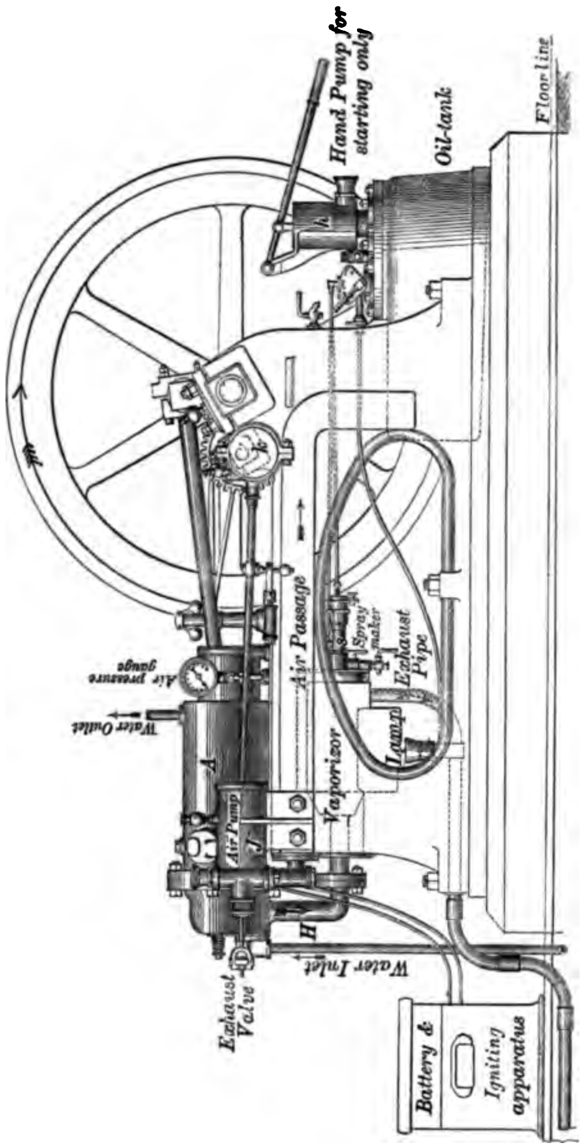

Fig. 322.

sponge or other porous material. The air entering at F serves only to atomise the petroleum, the main air supply being drawn in at O and through a valve, S. After passing through the carburettor, the air, which is then saturated with vapour, enters a chamber, C, which is constantly filled with flame, and is there ignited, the explosive combustion driving out the piston. The carburettor is separated from the chamber, C, by perforated metal plates which prevent the passage of flame. Ignition is effected in starting the engine, by inserting a match at G. After one-third of the piston stroke, the valve, S, closes, and the charge expands during the remainder of the stroke. The products of combustion are expelled during the return stroke.

Mr. Donkin gives the following as the requirements which an oil engine should meet:—"It should be—(1) self-contained and quite independent, having everything requisite for its efficient working for a certain length of time. (2) Safe and simple, using as the working agent a combustible which is neither difficult to procure nor dangerous to transport. (3) Easy to handle, so that any ordinary unskilled workman can drive it. This is advisable, because these engines are frequently placed in the hands of labourers without any knowledge of machinery. (4) Compact and easily transported from place to place. (5) Economical in working." Preference is now generally given to those engines in which ordinary kerosene is employed, and the "cycle" (*i.e.*, the relation between the explosion, the piston-stroke, and the discharge of the combustion products) enunciated in the 1862 patent of Beau de Rochas has been almost universally adopted. In this, one explosion occurs for each two revolutions of the crank shaft. The first forward stroke of the piston draws in the charge; and the return stroke compresses it. During the next forward stroke, the explosion actuates the piston, and on the return stroke, the combustion products are discharged. The Priestman, Hornsby-Akroyd, and Trusty engines may be taken as typical of the principal forms of oil motors in use, and will now be described.

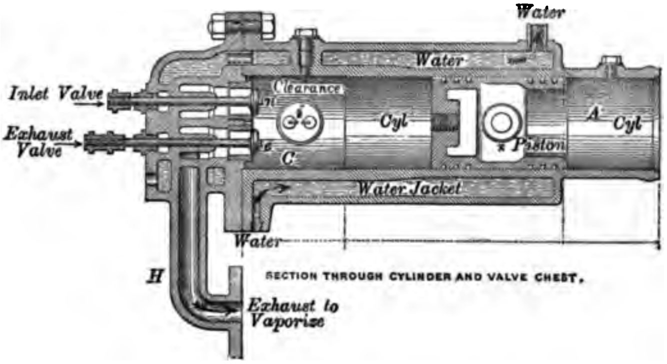

Fig. 323.

The **Priestman** engine (Figs. 322 and 323), which was brought out in 1888 and is now very largely used, is generally worked with kerosene, but oils of lower volatility may be employed. Ordinary lift valves are used in this and most other oil engines, as they are much less liable to become clogged. The oil tank, which is fitted with a hand-pump, *h*, for use in starting the engine, contains sufficient oil to last for two or three days. Figs. 324 and 325 are enlarged views of the spray-maker and vaporiser.

A small air-pump, J, worked by the eccentric, *k*, which also controls the exhaust valve, draws in air through a cotton-wool filter and compresses it into the oil tank, at a pressure of from 8 to 15 lbs. above the atmospheric pressure. Streams of oil and air are thus driven into the spray-producer, S (Fig. 322), through two concentric nozzles. The nozzles are peculiarly shaped, so that the oil is forced in very fine spray into the vaporiser, the amount of the charge thus entering, being adjusted by the governor to the speed at which the engine is working. As the spray enters the vaporiser, the in-stroke of the motor piston draws in air through a non-return valve, G, and a throttle valve, F (Fig. 324). The air enters the vaporiser through a number of small holes, *d*, breaking up and mixing with the spray which it sweeps forward into the cylinder. The vaporiser consists of a front portion in which admixture occurs as described, and a back portion in which the oil in the charge is volatilised by the heat of the exhaust gases (the products of combustion of the previous charge) which are led through a pipe, H (Fig. 323), around the vaporising chamber. This heating is essential, as the oil would otherwise partially separate from the spray before reaching the cylinder.

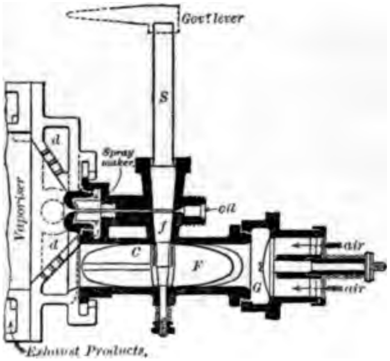

Fig. 324.

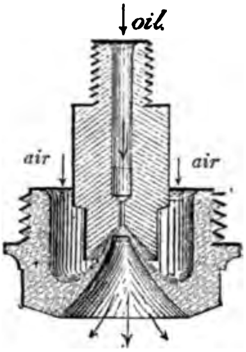

Fig. 325.

The ignition of the charge in the cylinder is effected as follows:— A battery on the base plate of the engine is connected with platinum wires, *i* (Fig. 323), in the compression space of the motor cylinder, and the spark passes when contact is established by a projection on the rod of the eccentric, *k* (Fig. 322).

The engine works on the four-cycle principle already referred to. The first out-stroke draws in the charge; the return stroke compresses it into the space, C, at the back of the cylinder; when the piston reaches the inner dead point, the spark fires the charge and the piston

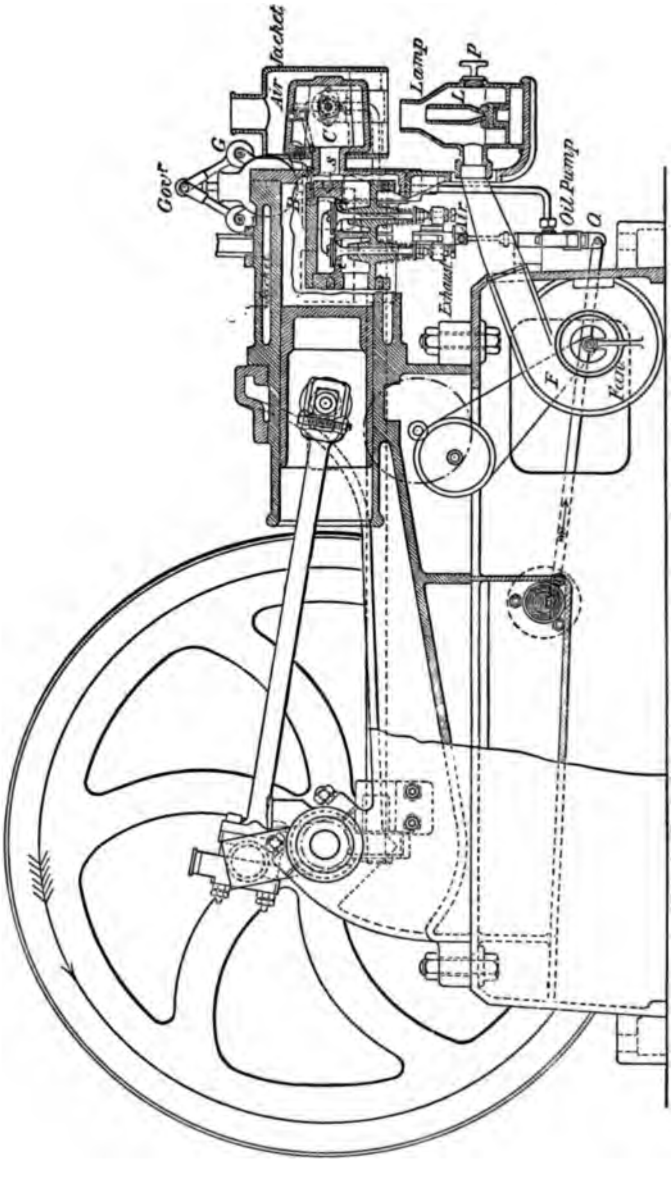

Fig. 326.

is propelled. On the return stroke, the combustion products pass through the valve, *e*, which is opened by the eccentric, and after passing round the vaporiser, escape into the atmosphere. The working is controlled by a governor, the entrance of oil being thus regulated by means of the spindle, S (Fig. 324), which has a V-shaped opening at *f*, and the supply of air being adjusted by the use of a throttle, F. As a portion of the oil is always condensed upon the cylinder, no other lubrication of the piston is required.

The working cylinder is surrounded by a water jacket as in gas engines, to prevent the accumulation of heat. The loss of power arising from this cooling, was estimated by Professor Unwin, in the case of a 5 H.P. engine, at 47·54 per cent., and the loss from the heat remaining in the exhaust gases, at 26·72 per cent., the total heat utilised being 16·12 per cent.

In the **Hornsby-Akroyd** oil engine (Fig. 326), the explosion is effected by injecting the oil into a red-hot chamber ("cartridge") C, into which heated air is forced by the piston. The mixture ignites spontaneously as the piston reaches the inner dead-point, and the return stroke is thus produced. The engine works on the four-cycle system employed in the "Priestman." The cartridge, C, is kept at a uniform temperature by an air jacket, and is heated at starting by means of a lamp, L, fed with oil from the tank which supplies the engine. A fan, F, worked by hand, supplies air to the lamp, and the oil burns from a small piece of asbestos or other absorbent material, inserted at P. After the chamber, C, is heated, the working of the engine suffices to maintain its temperature.

The air and exhaust valves, *c d*, are controlled from a shaft driven at half-speed by the crank shaft. They communicate with the cylinder through the same opening, so that the heat of the exhaust warms the fresh air as it enters. This air is driven by the piston into the cartridge and there mixes with the vapour of a very small quantity of oil which is injected through a nozzle, but without being sprayed, by a pump, O. When the inner dead point of the piston is reached, the explosion occurs and the gases travel through a small passage, *s*, into the compression-space, B, of the cylinder. The governor, G, controls a small valve through which the oil enters the cartridge, C, and a bye-pass valve which allows the oil to return to the tank when not utilised. A water-jacket round the valve box keeps the oil cool until it reaches the cartridge.

With this engine, oil of specific gravity 0·850 and flashing point 150° F. is stated to be generally used. Only about 0·015 of a cubic inch of oil is injected at each stroke of the pump, O, in the case of a 6 horse-power engine.

In the **Trusty** oil engine (Fig. 327) of Messrs Wyman and Hitchcock, which is also of the four-cycle type, the oil is drawn through a pipe, *p*, from a tank below the engine, by a pump, P, and is forced through a pipe, p^1, into a receiver, C. From this, it passes drop by drop into the cylinder jacket or vaporiser, V, through a glass tube and a valve, H. The jacket is sufficiently hot to volatilise the oil, and the vapour is drawn, together with air admitted by a valve, S^1, into the compression end of the cylinder. On the return stroke of the piston, a portion of the mixture passes into an igniting tube, I, and the charge is exploded. The tube, I, is maintained at a red heat by a lamp, J.

The oil-pump rod, Q, is actuated by a hit-and-miss device, M, controlled by a pendulum governor, G. A lever, D, is interposed so that the pump is not worked if the speed become excessive. The lever also acts upon the valve, H, the oil supply being thus doubly-controlled. The air and exhaust valves, $S S^1$, are adjusted by screws, $O O^1$, and are controlled through levers, $L L^1$, from a shaft driven at half-speed from the crank shaft. The exhaust outlet is at E.

In this engine, Broxburn lighthouse oil of specific gravity 0·81 and flashing point 150° F. is generally used. The engine runs at high speeds and gives a good heat efficiency.

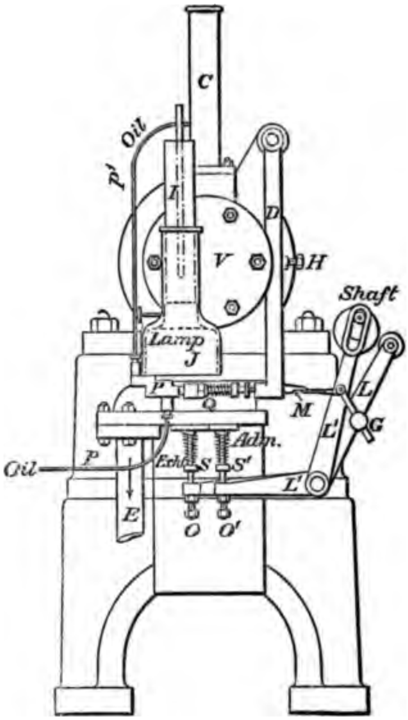

Fig. 327.

Considerable attention has recently been directed in France, to the use of petroleum motors for the propulsion of road carriages, and a practical demonstration of the perfection to which the construction of such vehicles has been brought in that country has been afforded by the results of a race from Paris to Bordeaux. In this contest the first prize was for a four-seated vehicle, and it was won by MM. Les fils de Peugeot Frères, of Valentigney (Doubs), whose carriage travelled at an average speed of 13 miles an hour, and covered the distance from Paris to Bordeaux and back under sixty hours. A still shorter time was occupied by the two-seated vehicle of MM. Panhard and Levassor, of Paris, to whom the second prize was awarded.

The Daimler petroleum engine, made by Panhard and Levassor, is employed by both the firms named. It is driven by the explosion in the cylinder of a mixture of air with the vapour of ordinary petroleum spirit (benzoline) of specific gravity 0·700 to 0·705, and it is claimed that it is distinguished from other motors of the same type by the employment of a more powerful gaseous mixture, and by the high speed at which it runs. The petroleum spirit is contained in a carburettor fixed at the side of the cylinder, and the ignition of the charge is effected by the compression of a portion of the gaseous mixture into a capsule heated to redness by a flame applied to the exterior. The motor is made in various sizes, from ½ to 10 horse-power, and may have one, two, or four cylinders.

The carriages of Les fils de Peugeot Frères are built of steel tubing, and are fitted with india-rubber-tired wheels, similar to those employed for bicycles. A Daimler motor of the two-cylinder type is used. The motor of the two-seated vehicle is from 1½ to 2½ horse-power, and of the four-seated from 2¼ to 3¼ horse-power. The weight of the smaller carriages empty is about 400 kilos., and of the larger about 600 kilos. The speed, when loaded, allowing an average weight of 75 kilos. for each person carried, is from 4 to 5 kilometres per hour up inclines of 8 to 10 per cent., and from 15 to 18 kilometres on the level, assuming that the roads are well made and in good condition. The cost of the petroleum spirit consumed per kilometre traversed, is reckoned at 4 to 5 centimes, and the cost of maintenance at about 4 centimes, the latter including the expense of renewal of the india-rubber tires, which are considered to last for 8,000 kilometres. The cost of a carriage to hold four is 5,600 francs.

The carriages of Panhard and Levassor are, unless otherwise ordered, fitted with iron-tired wooden wheels, and a four-seated vehicle is supplied for 5,000 francs. The petroleum spirit reservoir is stated to contain a supply sufficient for a journey of 80 kilometres. The quantity of water carried for the cooling of the motor cylinders is 35 litres, and this should be renewed every 50 kilometres.

The "Zephyr" launch-engine, introduced in this country by Messrs. Yarrow, is of particular interest, as the vapour of petroleum spirit, of specific gravity 0·68, is employed in the same manner as steam, as a motive power. While the vapour of such petroleum spirit may be cooled to 130° F. without condensation, it exerts a vapour pressure of 10 lbs. per square inch at 155° F., and of 40 lbs. per inch at 212° F., at which temperature water, of course, has a vapour pressure of about 15 lbs. For the same amount of heat, therefore, petroleum spirit gives a higher pressure than does water, and a correspondingly smaller amount of heat is lost in the exhaust, so that a higher heat-efficiency is obtained. Meiro[1] states that although the vapour pressures of different samples vary considerably at low temperatures, there is practically no difference at temperatures above 85° C. Thus, one sample of specific gravity 0·71 showed a pressure of 0·065 kilo. per square centimetre at 29° C., while another sample of specific gravity 0·715 yielded that pressure at 43° C. Both samples gave a pressure of about 2 atmospheres at 85° C. The working of the engine is similar to that of a surface-condensing steam engine. The engine and vapour-generator are carried in the stern of the boat, and the reservoir of spirit in the bow. The spirit is volatilised in a spiral tube enclosed in a non-conducting casing and heated by a burner. The vapour propels the piston as in a steam engine, and exhausts into two cooling pipes, from which the condensed liquid returns to the reservoir. Thus, the spirit is used repeatedly without coming into contact with the air, and only a comparatively small quantity of spirit has to be stored.

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[1] *Chem. Zeit. Rep*, 1893, 158.

The vaporiser may be heated by burning part of the petroleum spirit in an atmospheric burner, but the better and commoner plan is to use ordinary kerosene. This is sprayed by a small air-pump driven by the engine, and is burned in a fire-box beneath the vaporiser after being mixed with a further supply of air. The consumption of kerosene for fuel amounts to about a third of a gallon per horse-power per hour.

SECTION XI.

STATUTORY, MUNICIPAL, AND OTHER REGULATIONS RELATING TO THE TESTING, STORAGE, TRANSPORT, AND USE OF PETROLEUM AND ITS PRODUCTS.

BRITISH.

As the general use of mineral oils as illuminating agents may be said to date only from 1859, all legislation in relation to petroleum has been effected within comparatively recent years. In this country, the first Act was passed in 1862 (25 and 26 Vict., ch. 66). It was entitled "An Act for the safe-keeping of petroleum," and the preamble was as follows:—

> "Whereas it is expedient to provide for the safe-keeping of petroleum and certain products thereof that are dangerous to life and property, from their properties of giving off inflammable vapours at low temperatures," &c.

This Act defined "petroleum" for the purposes of the Act as including "any product thereof that gives off an inflammable vapour at a temperature of less than 100° of Fahrenheit's thermometer." Not more than 40 gallons of "petroleum" (as defined in the Act) was to be stored within 50 yards of a dwelling-house or warehouse, except under license from the local authority, who might impose any conditions considered necessary for the public safety. Carriage in a vessel within a harbour was subject to the regulations of the harbour authorities only, and the powers of search given in the Gunpowder Act, 1860, were extended to "petroleum" under this Act. As no method of testing was specified, it was practically impossible to put the Act into operation.

An amending Act was accordingly passed in 1868 (31 and 32 Vict., ch. 56), and in this there was an extended definition of "petroleum" which has been given in Section IX. (p. 550). In this Act, which "so far as is consistent with the tenor thereof" was directed to be read as one with the previous Act, storage without a license, within the 50 yards limit, was disallowed, except in the case of petroleum for private use, and as regards such petroleum, no limit of quantity was fixed. The "bottle or vessel" containing "petroleum" (as defined in the Act) was required to bear the following label:—

> "Great care must be taken in bringing any light near to the contents of this vessel, as they give off an inflammable vapour at a temperature of less than 100° of Fahrenheit's thermometer."

Any duly appointed inspector of weights and measures was empowered to "inspect and test all petroleum kept, offered, or exposed for sale," and any petroleum so kept, or offered, or exposed for sale in contravention of that Act, or of the previous Act, was liable to be seized, and upon conviction, forfeited, the person or persons offending being liable to a penalty of five pounds. Such person or persons might, however, appeal against the test of the inspector, and in such case, the court might submit the question to the public analyst, or if no such official had been appointed, to "some other person having competent chemical knowledge."

The practical effect of this legislation was that two classes of petroleum products were imported into this country, one (kerosene) conforming, or intended to conform, to the requirements of the law, and the other (petroleum spirit) giving off inflammable vapour at all ordinary temperatures, and even far below them.

In 1871, another Act (34 and 35 Vict., ch. 105) was passed, and as this is still in force, except as to the standard or limit of test and the mode of testing, it is given below in full, the schedules only being omitted. The first of these schedules is a reproduction of the directions for testing given in the schedule of the Act of 1868, and the second specifies the Acts repealed by Section 17, as follows:—The Petroleum Act, 1862, the Carriage and Deposit of Dangerous Goods Act, 1866, and the Petroleum Act, 1868. This Act was to continue in force until 1st October, 1872, but was continued from year to year by the Expiring Laws Continuance Acts.

CHAP. 105.

An Act for the safe keeping of Petroleum and other substances of a like nature. [21st August, 1871.] A.D. 1871.

WHEREAS it is expedient to consolidate and amend the law relating to the safe keeping of petroleum and other substances of a like nature:

Be it enacted by the Queen's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:

1. This Act may be cited as "The Petroleum Act, 1871." Short title of Act.

2. In this Act, if not inconsistent with the context, the following terms have the meanings hereinafter assigned to them; (that is to say,) Interpretation of certain terms in the Act:

The term "borough" means— "Borough:"

In England any place for the time being subject to the provisions of the Act of the session of the fifth and sixth years of the reign of King William the Fourth, chapter seventy-six, "to provide for the regulation of municipal corporations in England and Wales," and the Acts amending the same;

In Scotland any royal burgh and any burgh or town returning or contributing to return a member or members to serve in Parliament;

In Ireland any place for the time being subject to the provisions of the Act of the session of the third and fourth years of the reign of Her present Majesty, chapter one hundred and eight, "for the regulation of municipal corporations in Ireland, and the Acts amending the same:"

The term "person" includes a body corporate: "Person:"

The term "Secretary of State" means one of Her Majesty's Principal Secretaries of State: "Secretary of State:"

The term "Lord Lieutenant" means the Lord Lieutenant of Ireland or the lords justices or other chief governors or governor of Ireland for the time being: "Lord Lieutenant:"

The term "harbour" means any harbour properly so called, whether natural or artificial, and any port, haven, estuary, tidal river or other river, canal or inland "Harbour:"

navigation navigated by sea-going ships, and any dock, pier, jetty, or other works in or at which ships do or can ship or unship goods or passengers:

"Harbour authority:"

The term "harbour authority" includes any persons or person being or claiming to be proprietors or proprietor of or intrusted with the duty or invested with the power of improving, maintaining, or managing any harbour:

"Ship:"

The term "ship" includes every description of vessel used in navigation, whether propelled by oars or otherwise:

"Summary Jurisdiction Acts:"

The term "Summary Jurisdiction Acts" means as follows:

As to England, the Act of the session of the eleventh and twelfth years of the reign of Her present Majesty, chapter forty-three, intituled "An Act to facilitate the performance of the duties of justices of the peace out of sessions within England and Wales with respect to summary convictions and orders," and any Acts amending the same;

As to Scotland, "The Summary Procedure Act, 1864;"

As to Ireland, within the police district of Dublin metropolis, the Acts regulating the powers and duties of justices of the peace for such district, or of the police of such district; and elsewhere in Ireland, "The Petty Sessions (Ireland) Act, 1851," and any Act amending the same:

"Court of Summary Jurisdiction:"

The term "Court of Summary Jurisdiction" means and includes any justice or justices of the peace, sheriff or sheriff substitute, metropolitan police magistrate, stipendiary or other magistrate, or officer, by whatever name called, to whom jurisdiction is given by the Summary Jurisdiction Acts or any Acts therein referred to, or to proceedings before whom the provisions of the Summary Jurisdiction Acts are or may be made applicable:

"County rate."
31 & 32 Vict. c. 82.

The term "county rate" means as regards Scotland the county general assessment leviable in pursuance of "The County General Assessment (Scotland) Act, 1868," and as regards Ireland the grand jury cess.

Definition of "petroleum" and application of Act.

3. For the purposes of this Act the term "petroleum" includes any rock oil, Rangoon oil, Burmah oil, oil made from petroleum, coal, schist, shale, peat, or other bituminous substance, and any products of petroleum, or any of the above-mentioned oils; and the term "petroleum to which this Act applies," means such of the petroleum so defined as, when tested in manner set forth in Schedule One to this Act, gives off an inflammable vapour at a temperature of less than one hundred degrees of Fahrenheit's thermometer.

Byelaws as to ship carrying petroleum.

4. Every harbour authority shall frame and submit for confirmation to the Board of Trade byelaws for regulating the place or places at which ships carrying petroleum to which this Act applies are to be moored in the harbour over which such authority has jurisdiction, and are to land their cargo, and for regulating the time and mode of, and the precautions to be taken on, such landing. The harbour authority shall publish the byelaws so framed with a notice of the intention of such authority to apply for the confirmation thereof. The Board of Trade may confirm such byelaws with or without any omission, addition, or alteration, or may disallow the same.

Every such byelaw when confirmed shall be published by the harbour authority, and may be from time to time altered or repealed by a byelaw made in like manner. Byelaws under this section shall be published in such manner as the Board of Trade may from time to time direct.

If at any time it appears to the Board of Trade that there is no bye-law for the time being in force under this section in any harbour the Board of Trade may, by notice, require the harbour authority of such harbour to frame and submit to them a byelaw for the purposes of this section, and if such harbour authority make default in framing a byelaw and obtaining the confirmation thereof within the time limited by such notice the Board of Trade may make a byelaw for the purposes of this section, and such bye-law shall have the same effect as if it had been framed by the harbour authority and confirmed by the Board of Trade.

Where any ship or cargo is moored, landed, or otherwise dealt with in contravention of any bye-law for the time being in force under this Act in any harbour, the owner and master of such ship, or the owner of such cargo, as the case may be, shall each incur a penalty not exceeding fifty pounds for each day during which such contravention continues, and it shall be lawful for the harbour master or any other person acting under the orders of the harbour authority of such harbour to cause such ship or cargo to be removed, at the expense of the owner thereof, to such place as may be in conformity with the said byelaw, and all expenses incurred in such removal may be recovered in the same manner in which penalties are by this Act made recoverable.

Notice by owner or master of ship carrying petroleum.

5. The owner or master of every ship carrying a cargo any part of which consists of petroleum to which this Act applies, on entering any harbour within the United Kingdom, shall give notice of the nature of such cargo to the harbour authority having jurisdiction over such harbour.

If such notice is not given the owner and master of such ship shall each incur a penalty not exceeding the sum of five hundred pounds, unless it is shown to the satisfaction of the court before which the case is tried that neither the owner nor the master knew the nature of the goods to which the proceedings relate, nor could with reasonable diligence have obtained such knowledge.

Label on vessels containing petroleum.

6. Where any petroleum to which this Act applies—

(*a*) Is kept at any place except during the seven days next after it has been imported; or,

(*b*) Is sent or conveyed by land or water between any two places in the United Kingdom; or,

(*c*) Is sold or exposed for sale;

the vessel containing such petroleum shall have attached thereto a label in conspicuous characters, stating the description of the petroleum, with the addition of the words "highly inflammable," and with the addition—

(*a*) In the case of a vessel kept, of the name and address of the consignee or owner:

(*b*) In the case of a vessel sent or conveyed, of the name and address of the sender:

(*c*) In the case of a vessel sold or exposed for sale, of the name and address of the vendor.

All petroleum to which this Act applies which is kept, sent, conveyed, sold, or exposed for sale, in contravention of this section, shall, together with the vessel containing the same, be forfeited, and in addition thereto the person keeping, sending, selling, or exposing for sale the same shall for each offence be liable to a penalty not exceeding five pounds.

Regulations as to storage of petroleum.

7. Save as hereinafter mentioned, after the passing of this Act petroleum to which this Act applies shall not be kept, except in pursuance of a license given by such local authority as is in this Act mentioned.

All petroleum kept in contravention of this section shall, together with the vessel containing the same, be forfeited, and in addition thereto the occupier of the place in which such petroleum is so kept shall be liable to a penalty not exceeding twenty pounds a day for each day during which such petroleum is so kept.

This section shall not apply to any petroleum kept either for private use or for sale, provided the following conditions are complied with:

(1.) That it is kept in separate glass, earthenware, or metal vessels, each of which contains not more than a pint, and is securely stopped:

(2.) That the aggregate amount kept, supposing the whole contents of the vessels to be in bulk, does not exceed 3 gallons.

Definition of local authority.

8. The following bodies shall respectively be the local authority to grant licenses under this Act in the districts hereinafter mentioned; (that is to say,)

(1.) In the City of London, except as hereafter in this section mentioned, the Court of the Lord Mayor and aldermen of the said city:

(2.) In the Metropolis (that is, in places for the time being within the jurisdiction of the Metropolitan Board of Works, under the Metropolis Management Act, 1855), except the City of London, and except as hereafter in this section mentioned, the Metropolitan Board of Works:

(3.) In any borough in England or Ireland, except as hereafter in this section mentioned, the Mayor, aldermen, and burgesses acting by the council:

(4.) In any place in England or Ireland, except as hereafter in this section mentioned, within the jurisdiction of any trustees or improvement commissioners appointed under the provisions of any local or general Act of Parliament, and not being a borough, or comprising any part of a borough, the trustees or commissioners:

(5.) In any place in England, except as hereafter in this section mentioned, within the jurisdiction of a local board constituted under the Local Government Act, 1858, and not being any of the districts before-mentioned, or comprising any part of any such district, the local board:

(6.) In any burgh in Scotland, except as hereafter in this section mentioned, the town council:

(7.) In any place in Scotland, except as hereafter in this section mentioned, within the jurisdiction of police commissioners, or trustees exercising the functions of police commissioners under any general or local Act, and not being a burgh, or comprising any part of a burgh, the police commissioners or trustees:

(8.) In any harbour within the jurisdiction of a harbour authority, whether situate or not within the jurisdiction of any local authority before in this section mentioned, the harbour authority, to the exclusion of any other local authority:

(9.) In any place in which there is no local authority, as before in this section defined, in England or Ireland, the justices in petty sessions assembled, and in Scotland, any two or more justices of the peace for the county, sitting as judges in the justice of peace court.

Mode of granting licenses.

9. Licenses in pursuance of this Act shall be valid if signed by two or more of the persons constituting the local authority, or executed in any other way in which other licences, if any, granted by such authority, are executed. Licenses may be granted for a limited time, and may be subject to renewal or not in such manner as the local authority think necessary.

There may be annexed to any such license such conditions as to the mode of storage, the nature and situation of the premises in which, and the nature of the goods with which petroleum, to which this Act applies, is to be stored, the facilities for the testing of such petroleum from time to time, the mode of carrying such petroleum within the district of the licensing authority, and generally as to the safe keeping of such petroleum as may seem expedient to the local authority.

Any licensee violating any of the conditions of his license shall be deemed to be an unlicensed person. There may be charged in respect of each license granted in pursuance of this Act such sum, not exceeding five shillings, as the local authority may think fit to charge.

In case of refusal of license the applicant may memorialise Secretary of State or Lord Lieutenant.

10. If on any application for a license under this Act the local authority refuse the license, or grant the same only on conditions with which the applicant is dissatisfied, the local authority shall, if required by the applicant, deliver to him in writing, under the hand or hands of one or more of the persons constituting the local authority, a certificate of the grounds on which they refused the license, or annexed conditions to the grant thereof.

The applicant, within ten days from the time of the delivery of the certificate, may transmit the same to a Secretary of State if the application is for a license in England or Scotland, and to the Lord Lieutenant if the application is for a license in Ireland, together with a memorial, praying that notwithstanding such refusal, the license may be granted, or that the conditions may not be imposed, or may be altered or modified in such manner and to such extent as may be set forth in such memorial.

It shall be lawful for the Secretary of State, or the Lord Lieutenant, if he think fit, on consideration of such memorial and certificate, and, if he think it necessary or desirable, after due inquiry and a report by such person as he may appoint for that purpose, to grant the license prayed for, either absolutely or with such conditions as he thinks fit, or to alter or modify the conditions imposed by the local authority; and the license so granted, or altered and modified as the case may be, when certified under the hand of a Secretary of State, or the Lord Lieutenant, shall be to all intents as valid as if granted by the local authority.

Testing of petroleum by officer of local authority.

11. Any officer authorised by the local authority may purchase any petroleum from any dealer in it, or may, on producing a copy of his appointment, purporting to be certified by the clerk or some member of the local authority, or producing some other sufficient authority, require the dealer to show him every or any place,

and all or any of the vessels in which any petroleum in his possession is kept, and to give him samples of such petroleum on payment of the value of such samples.

When the officer has by either of the means aforesaid taken samples of petroleum, he may declare in writing to the dealer that he is about to test the same, or cause the same to be tested, in manner set forth in Schedule One to this Act, and it shall be lawful for him to test the same, or cause the same to be tested, at any convenient place at such resonable time as he may appoint, and the dealer or any person appointed by him may be present at the testing, and if it appear to the officer or other person so testing that the petroleum from which such samples have been taken is petroleum to which this Act applies, such officer or other person may certify such fact, and the certificate so given shall be receivable as evidence in any proceedings that may be taken against a dealer in petroleum in pursuance of this Act; but it shall be lawful for a dealer proceeded against to give evidence in proof that such certificate is incorrect, and thereupon the court before which any such proceedings may be taken may, if such court think fit, appoint some person skilled in testing petroleum to examine the samples to which such certificate relates, and to declare whether such certificate is correct or incorrect.

Any expenses incurred in testing any petroleum of such dealer in pursuance of this section shall, if such dealer be convicted of keeping, sending, conveying, selling, or exposing for sale, petroleum in contravention of this Act, be deemed to be a portion of the costs of the proceedings against him, and shall be paid by him accordingly. In any other event such expenses shall be paid by the local authority out of any funds for the time being in their hands, and in case the local authority are the justices, out of the county rate.

Penalty for refusing information and obstructing officer.

12. Any dealer who refuses to show to any officer authorised by the local authority every or any place, or all or any of the vessels in which petroleum in his possession is kept, or to give him such assistance as he may require for examining the same, or to give to such officer samples of such petroleum on payment of the value of such samples, or who wilfully obstructs the local authority, or any officer of the local authority, in the execution of this Act, shall incur a penalty not exceeding twenty pounds.

Search for petroleum. See 23 & 24 Vict. c. 139. s. 25.

13. Where any court of summary jurisdiction is satisfied by information on oath that there is reasonable ground to believe that any petroleum to which this Act applies is being kept, sent, conveyed, or exposed for sale within the jurisdiction of such court in contravention of this Act, at any place, whether a building or not, or in any ship or vehicle, such court shall grant a warrant, by virtue whereof it shall be lawful for any person named in such warrant to enter the place, ship, or vehicle named in such warrant, and every part thereof, and examine the same and search for petroleum therein, and take samples of any petroleum found therein, and if any petroleum to which this Act applies be found therein, which is kept, sent, conveyed, or exposed for sale in contravention of this Act, to seize and remove such petroleum, and the vessel containing the same, and to detain such petroleum and vessel until some court of summary jurisdiction has determined whether the same are or not forfeited, the proceedings for which forfeiture shall be commenced forthwith after the seizure.

Any person seizing any petroleum to which this act applies in pursuance of this section shall not be liable to any suit for detaining the same, or for any loss or damage incurred in respect of such petroleum, otherwise than by any wilful act or neglect while the same is so detained.

If any petroleum to which this Act applies is seized in pursuance of this section in any ship or vehicle, the person seizing the same may use for the purposes of the removal thereof, during twenty-four hours after the seizure, the said ship or vehicle, with the tackle, beasts, and accoutrements belonging thereto, and if he do so shall pay to the owner thereof a reasonable recompense for the use thereof, and the amount of such recompense shall, in case of dispute, be settled by the court of summary jurisdiction before whom proceedings for the forfeiture are taken, and may be recovered in like manner as penalties under this Act may be recovered.

Any person who, by himself or by any one in his employ or acting by his direction or with his consent, refuses or fails to admit into any place occupied by or under the control of such person, any person demanding to enter in pursuance of this section, or in any way obstructs or prevents any person in or from making any such search, examination, or seizure, or taking any such samples as authorised by this section, shall be liable to pay a penalty not exceeding twenty pounds, and to forfeit all petroleum to which this Act applies which is found in his possession or under his control.

Application of Act to other substances.

14. Her Majesty may from time to time make, revoke, and vary Orders in Council directing this Act or any part thereof to apply to any substance, and this Act, or the part thereof specified in the Order shall, during the continuance of the Order, apply to such substance, and shall be construed and have effect as if throughout it such substance had been included in the definition of petroleum to which this Act applies, subject to the following qualifications:

(1.) The quantity of any substance to which this Act is directed by Order in Council to apply, which may be kept without a license, shall be such quantity only as is specified in that behalf in such order, or if no such quantity is specified no quantity may be kept without a license:

(2.) The label on the vessel containing such substance shall be such as may be specified in that behalf in the order.

Summary proceedings for offences, penalties, &c.

15. In England and Ireland all offences and penalties under this Act, and all money and costs directed by this Act to be recovered as penalties, may be prosecuted and recovered in manner provided by the Summary Jurisdiction Acts.

In Scotland all offences and penalties under this Act, and all money and expenses by this Act directed to be recovered as penalties, shall, save as hereinafter provided, be prosecuted and recovered at the instance of the procurator fiscal or of any officer authorised in that behalf by the harbour authority or local authority under the provisions of the Summary Jurisdiction Acts before a court of summary jurisdiction, and all necessary powers and jurisdictions are hereby conferred on such court in Scotland.

Provided as follows:

1. A court of summary jurisdiction shall not impose a penalty exceeding fifty pounds, but any such court may impose that or any less penalty for any one offence, notwithstanding the offence involves a penalty of higher amount.

2. In Scotland any penalty exceeding fifty pounds shall be recovered and enforced in the same manner in which any penalty due to Her Majesty under any Act of Parliament may be recovered and enforced.

3. The "Court of Summary Jurisdiction," when hearing and determining an information or complaint, shall be constituted in some one of the following manners; (that is to say,)

(*a.*) In England, either of two or more justices of the peace in petty sessions sitting at a place appointed for holding petty sessions, or one of the magistrates hereinafter mentioned, sitting alone or with others at some court or other place appointed for the administration of justice; that is to say, the Lord Mayor, or any alderman of the City of London, a metropolitan police magistrate, a stipendiary magistrate, or some other officer or officers for the time being empowered by law to do alone or with others any act authorised to be done by more than one justice of the peace:

(*b.*) In Scotland, of two or more justices of the peace sitting as judges in a justice of the peace court, or of one of the magistrates hereinafter mentioned sitting alone or with others at some court or other place appointed for the administration of justice; that is to say, the sheriff of the county or his substitute, or the provost or other magistrate of a royal burgh, or some other officer or officers for the time being empowered by law to do alone or with others any act authorised to be done by more than one justice of the peace:

(*c.*) In Ireland, within the police district of Dublin Metropolis, of one of the divisional justices of the police district of Dublin metropolis, sitting at a police court within the said district; and elsewhere, of a stipendiary magistrate, sitting alone or with others, or of two or more justices of the peace in petty sessions, sitting at a place appointed for holding petty sessions.

4. The description of any offence under this Act in the words of such Act shall be sufficient in law.

5. Any exception, exemption, proviso, excuse, or qualification, whether it does

or not accompany the description of the offence in this Act, may be proved by the defendant, but need not be specified or negatived in the information, and if so specified or negatived no proof in relation to the matters so specified or negatived shall be required on the part of the informant or prosecutor.

6. No conviction or order made in pursuance of this Act shall be quashed for want of form or be removed by certiorari or otherwise, either at the instance of the Crown or of any private party, into any superior court. Moreover, no warrant of commitment shall be held void by reason of any defect therein, provided that there is a valid conviction to maintain such warrant, and it is alleged in the warrant that the party has been convicted.

7. All forfeitures may be sold or otherwise disposed of in such manner as the Court may direct.

8. In Scotland all penalties imposed under the provisions of this Act by a Court of Summary Jurisdiction may be enforced in default of payment by imprisonment for a term not exceeding three calendar months; and all such penalties recovered and the proceeds of all forfeitures sold under this Act shall be paid to the clerk of the Court of Summary Jurisdiction, and by him accounted for and paid to the persons and for the purposes under stated; (that is to say,)

(*a*) To the Queen's and Lord Treasurer's Remembrancer, on behalf of Her Majesty, when the Court is the Sheriff's Court:

(*b*) To the collector of county rates in aid of the general county assessment, when the Court is the Justice of the Peace Court:

(*c*) To the treasurer of the burgh in aid of the funds of the burgh when the Court is a Burgh Court.

9. In Ireland all penalties recovered under the provisions of this Act shall be applied according to the Fines (Ireland) Act, 1851, or any Act amending the same.

Reservation of previous powers with respect to inflammable substances.

16. All powers given by this Act shall be deemed to be in addition to and not in derogation of any other powers conferred on any local or harbour authority by Act of Parliament, law, or custom, and every local authority and harbour authority may exercise such other powers in the same manner as if this Act had not passed; and nothing in this Act contained shall be deemed to exempt any person from any penalty to which he would otherwise be subject in respect of a nuisance.

Repeal of Acts.

17. The Acts mentioned in Schedule Two to this Act are hereby repealed to the extent in that schedule mentioned.

Provided that such repeal shall not affect any Order in Council made, or any license granted, under any Act hereby repealed, or any liability or penalty incurred in respect of any offence committed before the passing of this Act, or any remedy or proceeding for enforcing such liability or penalty, and every such order, so far as relates to the matters provided for by this Act, and every such license, shall have effect as if it had been made or granted under this Act.

Duration of Act.

18. This Act shall continue in force until the first day of October, One thousand eight hundred and seventy-two, and no longer.

In 1879, a short Act was passed to legalise the Abel system of testing, and to substitute a test standard of 73° F. for the standard of 100° F., the new system of testing being found to afford a lower flashing point, with a given sample of oil, to an extent corresponding with that difference in temperature. This Act, which also provided for the continuance of the previous Act, is given in full, with the exception of the schedules prescribing the mode of testing, and specifying the portion of the Act of 1871 repealed. The schedule describing the mode of testing is given on pp. 556 to 559.

CHAP. 47.

A.D., 1879.

An Act to continue and amend the Petroleum Act, 1871.

[11th August, 1879.]

BE it enacted by the Queen's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:—

Short title and construction of Act.

1. This Act may be cited as the Petroleum Act, 1879.

This Act shall be construed as one with the Petroleum Act, 1871, and together with that Act may be cited as the Petroleum Acts, 1871 and 1879.

34 & 35 Vict. c. 105.

Alteration of test.

34 & 35 Vict. c. 105.

2. Whereas by the Petroleum Act, 1871, it is enacted that the term "petroleum to which this Act applies" means such of the petroleum defined by that Act as, when tested in manner set forth in Schedule One to that Act, gives off an inflammable vapour at a temperature of less than one hundred degrees of Fahrenheit's thermometer, and it is expedient to alter the said test: Be it therefore enacted that—

34 & 35 Vict. c. 105.

In the Petroleum Act, 1871, the term "petroleum to which this Act applies" shall mean such of the petroleum defined by section three of that Act as, when tested in manner set forth in Schedule One to this Act, gives off an inflammable vapour at a temperature of less than seventy-three degrees of Fahrenheit's thermometer.

34 & 35 Vict. c. 105.

Every reference in the Petroleum Act, 1871, to Schedule One to that Act shall be construed to refer to Schedule One to this Act.

Verification of test apparatus.

3. A model of the apparatus for testing petroleum, as described in Schedule One to this Act, shall be deposited with the Board of Trade, and the Board of Trade shall, on payment of such fee, not exceeding five shillings, as they from time to time prescribe, cause to be compared with such model and verified every apparatus constructed in accordance with Schedule One to this Act which is submitted to them for the purpose, and if the same is found correct shall stamp the same with a mark approved of by the Board and notified in the London Gazette.

An apparatus for testing petroleum purporting to be stamped with the said mark shall, until the contrary is proved, be deemed to have been verified by the Board of Trade.

All fees under this section shall be paid into the Exchequer.

Continuance of 34 & 35 Vict. c. 105.

4. The Petroleum Act, 1871, shall continue in force until otherwise directed by Parliament.

Commencement of Act.

5. This Act shall come into operation on the thirty-first day of December, one thousand eight hundred and seventy-nine, which day is in this Act referred to as the commencement of this Act.

Repeal of part of 34 & 35 Vict. c. 105.

6. The Petroleum Act, 1871, shall be repealed after the commencement of this Act to the extent in the third column of the Second Schedule to this Act mentioned.

34 & 35 Vict. c. 105.

Provided that any sample of petroleum taken before the commencement of this Act shall be tested in manner set forth in Schedule One to the Petroleum Act, 1871, and any offence committed before the commencement of this Act shall be prosecuted, and any investigation, legal proceeding, or remedy in relation to such offence, or to any act done before the commencement of this Act, shall be instituted, carried on, and have effect as if the provisions of this Act, other than those continuing the Petroleum Act, 1871, had not been passed.

34 & 35 Vict. c. 105.

After the Act of 1879 was passed, it was decided by the Court of Queen's Bench (Coleman *v.* Goldsmith, 43 J.P., p. 718, 8th November, 1881) that a cart could not be licensed under the Act of 1871 as a "place" for keeping petroleum to which the Act applies, and that such petroleum could not be hawked in a cart otherwise than in pursuance of a license under the Act. Accordingly, the following Act was passed in 1881:—

CHAP. 67.

An Act to regulate the hawking of Petroleum and other substances of a like nature. [27th August, 1881.]

A.D., 1881.

BE it enacted by the Queen's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:

Power to hawk petroleum. 34 & 35 Vict. c. 105.

1. Any person who is licensed in pursuance of the Petroleum Act, 1871, to keep petroleum to which that Act applies may, subject to the enactments for the time being in force with respect to hawkers and pedlars, hawk such petroleum by himself or his servants.

Regulations for hawking petroleum.

2. With respect to the hawking of petroleum to which the Petroleum Act, 1871, applies, the following regulations shall be observed:

(1) The amount of petroleum conveyed at one time in any one carriage shall not exceed twenty gallons:

(2) The petroleum shall be conveyed in a closed vessel so constructed as to be free from leakage:

(3) The carriage in which the vessels containing the petroleum are conveyed shall be so ventilated as to prevent any evaporation from the petroleum mixing with the air in or about the carriage in such proportion as to produce or be liable to produce an explosive mixture:

(4) Any fire or light or any article of an explosive or highly inflammable nature shall not be brought into or dangerously near to the carriage in which the vessels containing the petroleum are conveyed:

(5) The carriage in which the vessels containing the petroleum are conveyed shall be so constructed or fitted that the petroleum cannot escape therefrom in the form of liquid, whether ignited or otherwise:

(6) Proper care shall be taken to prevent any petroleum escaping into any part of a house or building, or of the curtilage thereof, or into a drain or sewer:

(7) The petroleum shall be stored in some premises licensed for keeping of petroleum and in accordance with the license for such premises both every night and also when the petroleum is not in the course of being hawked:

(8) All due precautions shall be taken for the prevention of accidents by fire or explosion, and for preventing unauthorised persons having access to the vessels containing the petroleum, and every person concerned in hawking the petroleum shall abstain from any act whatever which tends to cause fire or explosion, and is not reasonably necessary for the purpose of such hawking:

(9) No article or substance of an explosive or inflammable character other than petroleum, nor any article liable to cause or communicate fire or explosion, shall be in the carriage while such carriage is being used for the purpose of hawking petroleum:

In the event of any contravention of this section with reference to any petroleum, the petroleum, together with the vessels containing and the carriage conveying the same, shall be liable to be forfeited, and in addition thereto the licensee by whom or by whose servants the petroleum was being hawked shall be liable on summary conviction to a penalty not exceeding twenty pounds.

Provided that—

(1) Where some servant of the licensee or other person has in fact committed the offence, such servant or other person shall be liable to the same penalty as if he were the licensee:

(2) Where the licensee is charged with a contravention of this section, he shall be entitled upon information duly laid by him to have any other person whom he charges as the actual offender brought before the court at the time appointed for hearing the charge, and if the licensee proves to the satisfaction of the court that he had used due diligence to enforce the execution of this section, and that the said other person had committed the offence in question without his knowledge, consent, or connivance, the said other person shall be summarily convicted of such offence, and the licensee shall be exempt from any penalty.

Any petroleum other than that to which the Petroleum Act, 1871, applies while in any carriage used for the hawking of petroleum to which the Petroleum

Act, 1871, applies, shall for the purposes of this section be deemed to be petroleum to which the Petroleum Act, 1871, applies.

Modification of conditions of license under 34 & 35 Vict. c. 105.

3. Any conditions annexed to a license granted in pursuance of the Petroleum Act, 1871, either before or after the passing of this Act, shall, so far as they are inconsistent with this Act, be void, but save as aforesaid nothing in this Act shall affect the application to a licensee of the provisions of the Petroleum Act, 1871, or of any license granted thereunder.

Power of constable as to prevention of offences.

4. Where a constable or any officer authorised by the local authority has reasonable cause to believe that a contravention of this Act is being committed in relation to any petroleum, he may seize and detain such petroleum and the vessels and carriage containing the same, until some court of summary jurisdiction has determined whether there was or not a contravention of this Act, and section thirteen of the Petroleum Act, 1871, shall apply to such constable and officer as if he were the person named in the warrant mentioned in that section, and as if the seizure were a seizure in pursuance of that section.

Saving of rights of municipal boroughs.

5. Nothing in this Act contained shall extend to authorise the hawking of petroleum within the limits of any municipal borough in which, by any lawful authority, such hawking shall have been or may hereafter be forbidden.

6. For the purposes of this Act—

Definitions.

The expression "carriage" includes any carriage, waggon, cart, truck, vehicle, or other means of conveyance by land, in whatever manner the same may be drawn or propelled; and

A person shall be deemed for the purposes of this Act to hawk petroleum if by himself or his servants he goes about carrying petroleum to sell, whether going from town to town or to other men's houses, or selling it in the streets of the place of his residence or otherwise, and whether with or without any horse or other beast bearing or drawing burden.

Short title and construction of Act.

7. This Act may be cited as the Petroleum (Hawkers) Act, 1881.

34 & 35 Vict. c. 105.

42 & 43 Vict. c. 47.

This Act shall be construed as one with the Petroleum Acts, 1871 and 1879, and together with those Acts may be cited as the Petroleum Acts, 1871 to 1881.

After the passing of the Petroleum Act, 1879, the following memorandum, with drawings of the testing instrument, was issued by the Standards Office of the Board of Trade, this department being empowered to standardise the instruments to be placed in the hands of the inspectors appointed under the Act:—

PETROLEUM ACT, 1879.

REGULATIONS AS TO CONSTRUCTION AND VERIFICATION OF APPARATUS FOR TESTING PETROLEUM.

Form of Apparatus.

1. Every apparatus should be a copy, in form as well as in materials, of the model deposited with this Board. The form and dimensions of such model are shown on the accompanying diagrams.

2. No greater deviation than two one-hundredths (0·02) of an inch should be made in the dimensions of the slide and the square holes on the cover of the oil cup. In other parts of the apparatus a deviation of one-tenth of an inch will be allowed.

Thermometers.

3. Thermometers should be carefully graduated, as shown in plate [see Fig. 205].

Name Plate on certain Apparatus.

4. Apparatus required for the use of any Local Authority under the Petroleum Acts, should have the name of such Local Authority engraved on the front of the apparatus.

Delivery of Apparatus.

5. Apparatus should be delivered at this Office between 10 a.m. and 1 p.m. A written application or request should be sent with the apparatus, and when its comparison is completed, due notice will be sent to the applicant.

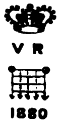
Each apparatus should be packed in a deal or mahogany box.

Fee of Verification.

6. On the verification of each apparatus a fee of five shillings will be charged.

Mark of Verification.

7. The mark of verification approved by the Board of Trade and notified in the *London Gazette*, is of the following design :—



Pendulum.

8. A model of the lead line or pendulum used with this apparatus may be seen at this Office.

Board of Trade,
Standards Office,
7 Old Palace Yard, Westminster,
1st January, 1880.

MUNICIPAL REGULATIONS.

The London County Council is the Local Authority under the Petroleum Acts for the Metropolis, outside of the area over which the Corporation of the City of London has jurisdiction. A report on the industries carried on in London, in which "petroleum" (as defined in the Acts of 1871 to 1881) is employed under license, was drawn up for the Council in 1890 by Mr. Alfred Spencer, Chief Officer of the Public Control Department, and is here appended, together with copies of the forms of licenses issued :—

London County Council.

Report as to licensed premises in the County of London, upon which petroleum, under the Acts, is used in trade or manufacture.

Presented to the Sanitary and Special Purposes Committee, 14th November, 1890.

PETROLEUM ACTS.

In accordance with the instructions of the committee at their meeting on the 31st October, that I should prepare a report submitting a list of the businesses carried on in London in which petroleum spirit is used in manufacturing processes or otherwise, I have to report as follows :—

The following is a list of the businesses, in which petroleum is so used, carried on in the county of London under the licenses of the Council :—

Dry Cleaners (21 licensed premises).
Helmet Manufacturers (5 licensed premises).
Tennis Shoe Manufacturers (4 licensed premises).
Indiarubber Manufacturers (12 licensed premises).
Waterproof Garment Manufacturers (41 licensed premises).
Glass Silverers (14 licensed premises).
Paint Manufacturers (6 licensed premises).
Glove Cleaners (41 licensed premises).

The licenses granted in respect of all these businesses have special conditions attached, with a view to safety, and in some cases these conditions appear to be fully adequate, as they probably reduce the danger in the particular processes carried on to the minimum. In some of the businesses, however, it may be desirable to make some addition to the existing precautions.

Whenever mineral spirit or its inflammable vapour is liable to be present in workrooms in dangerous quantity, the following precautions should, wherever possible, be adopted—

(*a*) The workroom should be a detached fireproof building on a level with the ground.

(*b*) The workroom should be well ventilated, both at the ground and ceiling levels.

(*c*) The workroom should be provided with doors opening outwards, in order to facilitate the escape of the workpeople in case of accident.

(*d*) The process in which mineral spirit is used should be carried on in closed vessels, and where that is not possible, the exposure of spirit should be reduced to a minimum, in order to lessen the formation of inflammable vapour.

(*e*) Such artificial light as would ignite inflammable vapour should be wholly excluded from workrooms in which mineral spirit is used. The only artificial light allowed should be incandescent electric light, or a form of gas light where the light is so enclosed as not to be in contact with the air of the workroom.

Taking the businesses in the order in which they appear in the above list, the first to be dealt with is—

1. **Dry Cleaners.**—In this business, mineral spirit is used, generally in large quantity, in the cleaning of dress material and other substances. The spirit is kept in specially constructed stores, and the cleaning takes place in specially constructed buildings.

Practically all the conditions for safety already indicated are insisted on by the conditions attached to licenses granted to dry cleaners in London.

Formerly, there were numerous accidents in connection with this business, but for the past few years, since the adoption of the indicated precautions, only one fire has occurred in London; and fortunately, on account of the isolation of the building and the precautions imposed by the license, no fatality or even personal injury resulted, nor did the fire extend beyond the actual building in which it broke out. It may be mentioned as an instance of the value of precautions in businesses of this nature, that on one of the dry cleaner's premises, before the present stringent conditions were insisted upon, the cleaning room was burnt out five times in six years; but that since the adoption of these precautions some seven years since, no fire has occurred on the premises.

2. **Helmet Manufacturers.**—In this business, a quantity of petroleum spirit, in no case exceeding 45 gallons, is used for the purpose of dissolving indiarubber, to form a solution used in cementing and waterproofing some forms of helmets. I do not consider the conditions attached to licenses for premises in which this business is carried on are sufficiently stringent. Difficulty was experienced in obtaining adequate arrangements for safety, both on account of the situation and construction of many of the premises. In every case, however, the petroleum spirit is kept, and the indiarubber solution is made, in a store which is as far as possible detached from the workrooms. The solution is used for cementing and waterproofing helmets, and in the room in which this is done, as well as in the place in which the helmets are afterwards dried, a considerable amount of inflammable vapour is given off. This vapour is to some extent carried off by ventilation, but

at present artificial light is used in some of the workrooms; and, looking to the recent fatal accident at a helmet manufacturer's in Cloth Fair, I think that such a method of lighting should no longer be permitted. No special provision is made upon any of the licensed helmet makers' premises for the escape of work-people in case of accident, and the Committee may consider it desirable in future to license only premises where adequate means of escape have been provided. I may, however, point out that no serious fire, or any fire involving loss of life, has occurred in recent years upon any of the licensed premises. The recent fatal fire on Messrs. Rowley & Brock's premises (which are in the city and under the jurisdiction of the Corporation of London) probably arose from the very grossest carelessness and the neglect of the most elementary precautions. An uncorked can containing a solution of naphtha and indiarubber was placed in the drying stove, and on the door of the stove being opened a volume of the vapour escaped and ignited.

Although no accident can be traced to the use of naked lights in workrooms where solution is used, it would undoubtedly reduce the danger if the Council insisted on the abolition of such lights and the substitution of the incandescent electric light or some perfectly safe form of gas lighting. In every case where a drying stove by fire heat is used, such stove should unquestionably be separated from the workrooms and ventilated into the external air, or in other words, it should be a distinct fire risk.

3. **Tennis Shoe Makers.**—In this trade, an indiarubber solution is used for cementing indiarubber soles to the uppers. The danger and the conditions are very similar to those in the case of helmet makers, and whatever the Committee decide as to the one trade should be applied to the other.

4. **Indiarubber Manufacturers.**—In this trade, indiarubber in bulk is dissolved in mineral spirit, and then mixed with other ingredients to form a plastic substance, which is worked up into various forms of indiarubber goods.

I think the arrangements for the storage of the naphtha and for dissolving the rubber are probably adequate at all the premises under the Council's license. After being taken out of the vessels in which it is dissolved, the indiarubber is of the consistency of dough, and it is so termed by the trade. It subsequently passes through a variety of machines, for manufacture into different articles, and during these processes some inflammable vapour is given off, but probably not in sufficient quantities to be liable to ignition. I recommend the Committee to in future attach a condition excluding fires and unsafe forms of artificial lighting, not only in the stores and mixing rooms as at present, but also in any workroom where there is a liability to the presence of inflammable vapour.

5. **Waterproof Garment Makers.**—This business is sometimes conducted on a very large scale in very large buildings, and in others on a small scale, and sometimes in dwellings. No matter how many or how few hands are at work, each of them requires a small quantity of solution and a small quantity of spirit. This is used for cementing the seams of the garments to be manufactured, and as there is but a small amount of vapour given off in the operations of each work-person, it is only where a large number of work-people are employed in one room that there is a liability to the formation of a large amount of inflammable vapour. The two points for the consideration of the Committee appear to be—

(1.) Whether fires and exposed artificial light should not be prohibited in all such workrooms.

(2.) Whether facilities for escape, in case of accident, should not be insisted upon, wherever a considerable number of hands are employed in one building.

By requiring both the solution and the naphtha to be used from suitable vessels, and by regulating the storage of the naphtha and the mixing of the solution, the Council has reduced the danger in these places; but the other points indicated are matters for serious consideration. I may point out, however, that there might be great difficulty in the case of the smaller makers, and of the work-people who carry on this business in their own homes, in providing a special artificial light, or special means of heating the rooms.

6. **Glass Silverers.**—In this business mineral spirit is used in the manufacture of the paint which covers the back of silvered glass. The spirit is usually kept and the paint mixed in the basement of the building where the business is carried

on, and it has been impracticable to obtain in such cases external places for the storage and the mixing. There is probably little danger in the process of applying the paint to the glass; and the point for the consideration of the Committee appears to be whether in future the storage and mixing should be allowed in the building in which the workrooms are situated.

7. **Glove Cleaning.**—In this business only small quantities of mineral spirit are used, and in a large number of cases the trade is so small that it can be carried on under the exemption contained in section 7 of the Petroleum Act, 1871, which permits three gallons of spirit to be kept without a license, provided it is kept in stoppered bottles which contain not more than 1 pint. The practice in London is that, where only one of these bottles is open at a time, no license is necessary, but whenever any larger quantity than 1 pint is opened for use at one time, a license is requisite. Although the quantity of petroleum used in glove cleaning is small, there is a considerable escape of inflammable vapour, and consequent danger. Upon every premises licensed by the Council, glove cleaning is required to be carried on in buildings either detached or external to the house or shop, and the presence of a fire or artificial light is forbidden. It is probably unnecessary to add to the restrictions already imposed on this business.

In addition to the foregoing, there are also a few other businesses in which petroleum spirit is used, and which are under the license of the Council, as follows:—

One bone boiler.
,, bedstead manufacturer.
,, photographic chemical manufacturer.
,, manufacturing chemist.
,, brassfitter (asbestos packing).
,, paraffin scale maker.
,, electrician (four licenses).
,, colour printing works.

I believe the conditions imposed in each of the above cases are adequate for safety.

The only remaining trade in which it is known that petroleum spirit is used, is that of toy balloon maker. Two premises upon which this trade is carried on are licensed, and at each 5 gallons may be kept. In both cases, the store is a sunk pit in the garden at rear of the dwelling, and this method is quite safe. The spirit is, however, taken in quantities not exceeding half a gallon, into a workroom in the upper part of the dwelling, where it is put into an open vessel, into which the indiarubber is dipped. No fire or light is allowed in this room, and the work is done with open windows, and it is probable that no further precaution can be adopted, except to require that the work be done in outbuildings only. The licensees are, however, so poor, that they are unable to provide these. These premises have been under license for some years, and the inspector reports that he has always found the business conducted with care.

LONDON COUNTY COUNCIL.

Petroleum Acts, 1871 *to* 1881.

ABSTRACT OF THE REGULATIONS AS TO THE KEEPING, SALE, CONVEYANCE, AND HAWKING OF PETROLEUM IN THE METROPOLIS.

This Abstract has no legal validity, and is intended only for the information and guidance of the persons concerned. For further information reference should be made to the Petroleum Acts, 1871 *and* 1879, *and to the Petroleum* (*Hawkers*) *Act*, 1881.

General.

Definition of petroleum. Sec. 3, 1871.

1. Petroleum to which the Acts apply means "any rock oil, Rangoon oil, Burmah oil, oil made from petroleum, coal, schist, shale, peat, or other bituminous substance, and any products of petroleum, or any of the above-mentioned oils," which, when tested in the prescribed manner, give off an inflammable vapour at a temperature of less than 73 degrees of Fahrenheit's thermometer.

Sec. 2, 1879, and Schedule 1.

2. Throughout this Abstract, petroleum to which the Acts apply is called "Petroleum," and all other petroleum is called "Petroleum Oil."

3. Where petroleum is—

(*a*) Kept at any place (except during the seven days next after importation); or,

(*b*) Sold or exposed for sale—

Labelling vessels. Sec. 6, 1871.

The vessel containing it shall have a label stating, in conspicuous characters, the description of petroleum, with the addition of the words "highly inflammable," and also the name and address of the owner or vendor.

Keeping petroleum. Sec. 7, 1871.

4. Petroleum can only be kept in pursuance of a license granted by the Council—

With the exception that not exceeding 3 gallons may be kept in separate glass, earthenware, or metal vessels, securely stopped, each of which must not contain more than 1 pint.

Licenses.

Applications. Sec. 9, 1871.

5. Application to the Council for a Petroleum License must be made upon the form provided for the purpose, which can be obtained by application in writing, addressed to the Chief Officer, Public Control Department of the London County Council, Spring Gardens.

Fees. Sec. 9, 1871.

6. Every application must be accompanied by a fee of five shillings in money, or, if sent through the post, by Cheque or Post Office Order payable to the order of the London County Council. The fee will be returned to the applicant if the Council does not grant a license.

Plans. Sec. 9, 1871.

7. Where the application is for a license to store 50 gallons of petroleum or more, there must also be sent a plan, drawn to the scale of one-eighth of an inch to a foot, and showing the proposed place and means of storage, and also showing the buildings, &c., within 50 feet of such place.

Particulars in application.

8. Every application must state—

(*a*) The quantity of petroleum which the applicant desires to keep.

(*b*) The proposed place and method of storage.

Mode of storage.

9. Petroleum should, whenever possible, be stored in one of the following methods:—

(*a*) In a strong metal tank sunk into the ground at a suitable place, and covered with earth or concrete. The tank to have no openings but for the pipes through which the petroleum is pumped.

(*b*) In a concrete, stone, brick, or iron store (partially sunk into the ground where possible), the lower part so constructed as to form a tank capable of receiving, in case of accident, all the petroleum contained in the store. The store to be ventilated sufficiently to prevent the accumulation therein of an inflammable vapour, and all ventilated openings to be protected by strong wire gauze.

The Council, however, grant licenses to keep quantities not exceeding 10 gallons of petroleum in yards or other suitable situations, on condition that a place of storage having a superficial area measuring at least 5 feet by 5 feet is provided, and is exclusively appropriated to the purpose, and that such place of storage is not within any inhabited building.

In cases where the foregoing methods of storage cannot be adopted, the Council may grant licenses under special conditions, provided the means of storage proposed are considered satisfactory.

General conditions in licenses. Sec. 9, 1871.

10. The following are the usual general conditions contained in Petroleum licenses granted by the Council:—

(1) (*The first condition describes the place and method of storage sanctioned at the particular premises licensed.*)

(2) That the place of storage aforesaid be in all respects kept and maintained in

the same condition that it was in when inspected by an authorised officer of the Council last before the granting of the license.

(3) That there be no fire, forge, furnace, or similar source of danger, or any storage of explosive substance within 20 feet, or of highly inflammable material within 10 feet, of such place of storage, unless separated therefrom by a wall or screen of sufficient strength and height to prevent the communication of fire.

(4) That no substance other than petroleum be deposited or kept in the place described in the first condition of the license.

(5) That the petroleum be exclusively contained in strong metal vessels, the openings to which are covered with fine wire gauze, and fitted with screw caps, and with secure taps so constructed and connected as to prevent leakage or the escape of vapour; and that such vessels and taps be kept in thoroughly good order.

(6) That there be kept painted in conspicuous characters on every storage vessel containing petroleum, the description of petroleum, with the addition of the words, "highly inflammable."

(7) That petroleum be only conveyed to or from the licensed premises in closed vessels, so constructed as to be entirely free from leakage.

(8) That no petroleum be conveyed to or from the licensed premises in a vehicle in which gunpowder or other article likely to cause fire or explosion is also carried.

(9) That petroleum be only received in or supplied from the licensed premises between sunrise and sunset; and that no artificial light or fire, or article likely to cause fire, be at any time taken into or near the place of storage.

(10) That the vessels containing petroleum be only opened upon the licensed premises at, or immediately adjoining, the place of storage, and for the time necessary for drawing off the petroleum; and that during such drawing off every reasonable precaution be taken for preventing the escape of petroleum or the vapour therefrom.

(11) That all petroleum received upon the premises be at once taken to the place of storage, and that petroleum taken from the place of storage for delivery or otherwise, be at once removed from the premises.

(12) That the licensee do take effectual precautions for preventing unauthorised persons, and all persons under the age of fifteen years, from obtaining access to the place of storage.

(13) That not less than a bushel of sand be kept with every vessel in which petroleum is stored, and that some portion of this be constantly kept immediately under the tap of the vessel.

(14) That due precaution be at all times taken for the prevention of accident from fire.

(15) That every authorised officer of the Council be at all times allowed free access to the premises of the licensee for the purpose of ascertaining if the above conditions are properly observed, and that the licensee do, by himself or his representatives, give any assistance for that purpose which such officer may require.

Duration of license. Sec. 9, 1871.

11. Licenses are granted for one year only, and, prior to expiration, application must be made for their renewal. Notice of the expiration, and a form of application for renewal, is sent to each licensee at the proper time.

Conveyance of Petroleum.

Conveyance of petroleum. Sec. 6, 1871.

12. Where petroleum is sent or conveyed, the vessel containing it shall have a label stating, in conspicuous characters, the description of petroleum, with the addition of the words, "highly inflammable," and also the name and address of the sender.

13. Petroleum conveyed to or from licensed premises must be conveyed in accordance with the conditions of the license.

Hawking Petroleum.

Hawking petroleum. Sec. 1, 1881

14. Any person allowed to keep petroleum may, subject to the enactments as to hawkers and pedlars, and to the following regulations, hawk petroleum by himself or his servants.

15. Section 2 of the Petroleum (Hawkers) Act, 1881, provides, with respect to the hawking of petroleum, that the following regulations shall be observed :—

Regulations as to hawking. Sec. 2, 1881.

(1) The amount of petroleum conveyed at one time in any one carriage shall not exceed 20 gallons.

(2) The petroleum shall be conveyed in a closed vessel, so constructed as to be free from leakage.

(3) The carriage in which the vessels containing the petroleum are conveyed shall be so ventilated as to prevent any evaporation from the petroleum mixing with the air in or about the carriage, in such proportion as to produce, or be liable to produce, an explosive mixture.

(4) Any fire or light, or any article of an explosive or highly inflammable nature, shall not be brought into or dangerously near to the carriage in which the vessels containing the petroleum are conveyed.

(5) The carriage in which the vessels containing the petroleum are conveyed shall be so constructed or fitted, that the petroleum cannot escape therefrom in the form of liquid, whether ignited or otherwise.

(6) Proper care shall be taken to prevent any petroleum escaping into any part of a house or building, or of the curtilage thereof, or into a drain or sewer.

(7) The petroleum shall be stored in some premises licensed for keeping of petroleum, and in accordance with the license for such premises, both every night and also when the petroleum is not in the course of being hawked.

(8) All due precautions shall be taken for the prevention of accidents by fire or explosion, and for preventing unauthorised persons having access to the vessels containing the petroleum, and every person concerned in hawking the petroleum shall abstain from any act whatever which tends to cause fire or explosion, and is not reasonably necessary for the purpose of such hawking.

(9) No article or substance of an explosive or inflammable character other than petroleum, nor any article liable to cause or communicate fire or explosion, shall be in the carriage while such carriage is being used for the purpose of hawking petroleum.

When petroleum oil is in a carriage used for hawking petroleum, such petroleum oil is deemed to be petroleum.

Inspection.

16. Any dealer who refuses to show to any officer authorised by the Council, every, or any place, or all or any of the vessels in which petroleum or petroleum oil in his possession is kept, or to give him such assistance as he may require for examining the same, or to give to such officer samples of such petroleum or petroleum oil, on payment of the value of such samples, or who wilfully obstructs the Council, or any officer of the Council, in the execution of this Act, shall incur a penalty not exceeding twenty pounds.

Refusing information or obstructing officer. Sec. 12, 1871.

ALFRED SPENCER,
Chief Officer, Public Control Department.

SPRING GARDENS,
CHARING CROSS, S.W.

LONDON COUNTY COUNCIL.

No. 90.
(Store License.)
Reg. No.

Petroleum Acts, 1871 *to* 1881.

PETROLEUM LICENSE.

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, the London County Council, being the Local Authority for the Metropolis under the said Acts (except as therein mentioned), doth hereby at the request of grant License to for the period of twelve calendar months from the to keep gallons of Petroleum, to which the Acts apply, and as defined in the said Acts, on the premises situate at in the parish of and within the jurisdiction of the said Council, subject to the conditions following, that is to say—

1. That the petroleum be kept only in a store substantially constructed entirely of concrete, stone, brick, or iron, and having a fireproof door which is to be kept locked at all times, except when petroleum is being placed in or removed from the store; that such store be not within any building, or abutting against a dwelling house; that the lower part of such store be so constructed as to form a tank capable of receiving and retaining, in case of accident, all the petroleum contained in the store; that the store be ventilated sufficiently to prevent the accumulation therein of an inflammable vapour, and that all ventilating openings be protected with strong wire gauze.

2. That such store be in all respects kept and maintained in the same condition that it was in when inspected by an authorised officer of the Council last before the granting of this license.

3. That there be no fire, forge, furnace, or similar source of danger, or any storage of explosive within 20 feet, or of highly inflammable material within 10 feet, of such store, unless separated therefrom by a wall or screen of sufficient strength and height to prevent the communication of fire.

4. That no substance other than petroleum be deposited or kept in the store.

5. That the petroleum be exclusively contained in strong metal vessels, the openings to which are covered with fine wire gauze and fitted with screw caps, and with secure taps, so constructed and connected as to prevent leakage or the escape of vapour; and that such vessels and taps be kept in thoroughly good order.

6. That there be kept painted in conspicuous characters, on every storage vessel containing petroleum, the description of petroleum, with the addition of the words "highly inflammable."

7. That petroleum be only conveyed to or from the licensed premises in closed vessels so constructed as to be entirely free from leakage.

8. That no petroleum be conveyed to or from the licensed premises in a vehicle in which gunpowder or other article likely to cause fire or explosion is also carried.

9. That petroleum be only received in or supplied from the licensed premises between sunrise and sunset; and that no artificial light or fire, or article likely to cause fire, be at any time taken into or near the store.

10. That the vessels containing petroleum be only opened upon the licensed premises at, or immediately adjoining, the store, and for the time necessary for drawing off the petroleum; and that during such drawing off every reasonable precaution be adopted for preventing the escape of petroleum or the vapour therefrom.

11. That all petroleum received upon the premises be at once taken to the store; and that petroleum taken from the store for delivery or otherwise, be at once removed from the premises.

12. That the licensee do take effectual precautions for preventing unauthorised persons and all persons under the age of fifteen years from obtaining access to the store.

13. That not less than a bushel of sand be kept with every vessel in which petroleum is stored; and that some portion of this be constantly kept immediately under the tap of the vessel.

14. That due precaution be at all times taken for the prevention of accident from fire.

15. That every authorised officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do by himself or his representatives give any assistance for that purpose which such officer may require.

By Order of the Council,

Clerk of the Council.

Section 9 of the Petroleum Act, 1871, provides that "any licensee violating any of the conditions of his license shall be deemed to be an unlicensed person."

This license is not transferable.

LONDON COUNTY COUNCIL.

No. 91.
(Storage Place License.)
Reg. No.

Petroleum Acts, 1871 *to* 1881.

PETROLEUM LICENSE.

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, the London
County Council doth hereby, at the request of M grant
License to for the period of twelve calendar months from the
to keep gallons of petroleum to which the
Acts apply, and as defined in the said Acts, on the premises situate at
in the parish of and within the County
of London, subject to the conditions following, that is to say—

1. That the vessel or vessels containing the petroleum be kept in a place of storage having a superficial area measuring at least 5 feet by 5 feet, that such place of storage be exclusively appropriated to the purpose, and that it be not within any inhabited building.

2. That the place of storage aforesaid be in all respects kept and maintained in the same condition that it was in when inspected by an authorised officer of the Council last before the granting of this license.

3. That there be no fire, forge, furnace, or similar source of danger, or any storage of explosives within 20 feet, or of highly inflammable material within 10 feet, of such place of storage, unless separated therefrom by a wall or screen of sufficient strength and height to prevent the communication of fire.

4. That no substance other than petroleum be deposited or kept in the place of storage.

5. That the petroleum be exclusively contained in strong metal vessels, the openings to which are covered with fine wire gauze and fitted with screw caps, and the vessels fitted with secure taps, so constructed and connected as to prevent leakage or the escape of vapour; and that such vessels and taps be kept in thoroughly good order.

6. That there be kept painted in conspicuous characters on every storage vessel containing petroleum, the description of petroleum, with the addition of the words "highly inflammable."

7. That petroleum be only conveyed to or from the licensed premises in closed vessels, so constructed as to be entirely free from leakage.

8. That no petroleum be conveyed to or from the licensed premises in a vehicle in which gunpowder or other article likely to cause fire or explosion is also carried.

9. That petroleum be only received in or supplied from the licensed premises between sunrise and sunset; and that no artificial light or fire, or article likely to cause fire, be at any time taken into or near the place of storage.

10. That the vessels containing petroleum be only opened upon the licensed premises at or immediately adjoining the place of storage, and for the time necessary for drawing off the petroleum, and that during such drawing off every reasonable precaution be adopted for preventing the escape of petroleum or the vapour therefrom.

11. That all petroleum received upon the premises be at once taken to the place of storage; and that petroleum taken from the place of storage for delivery or otherwise, be at once removed from the premises.

12. That the licensee do take effectual precautions for preventing unauthorised persons and all persons under the age of fifteen years from obtaining access to the place of storage.

13. That not less than a bushel of sand be kept with every vessel in which petroleum is stored, and that some portion of this be constantly kept immediately under the tap of the vessel.

14. That due precaution be at all times taken for the prevention of accident from fire.

15. That every authorised officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do, by himself or his representatives, give any assistance for that purpose which such officer may require.

Section 9 of the Petroleum Act, 1871, provides that "any licensee violating any of the conditions of his license shall be deemed to be an unlicensed person."

By Order of the Council,

Clerk of the Council.

SPRING GARDENS, S.W.

This license is not transferable.

No. 92.

(Special License.)

Reg. No.

LONDON COUNTY COUNCIL.

Petroleum Acts, 1871 *to* 1881.

PETROLEUM LICENSE.

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, the London County Council doth hereby, at the request of M grant License to for the period of twelve calendar months from the to keep gallons of Petroleum to which the Acts apply, and as defined in the said Acts, on the premises situate at in the parish of and within the jurisdiction of the said Council, subject to the conditions following, that is to say—

1. That the petroleum be kept only in

2. That the place of storage aforesaid be in all respects kept and maintained in the same condition that it was in when inspected by an authorised Officer of the Council last before the granting of this license.

3. That there be no fire, forge, furnace, or similar source of danger, or any storage of explosives within feet, or of highly inflammable material within feet, of such place of storage, unless separated therefrom by a wall or screen of sufficient strength and height to prevent the communication of fire.

4. That no substance other than petroleum be deposited or kept in the place described in the first condition of this license.

5. That, unless otherwise specially provided for in the first condition of this license, all petroleum kept upon the premises be exclusively contained in strong metal vessels, the openings to which are covered with fine wire gauze and fitted with screw caps, and with secure taps, so constructed and connected as to prevent leakage or the escape of vapour; and that such vessels and taps be kept in thoroughly good order.

6. That there be kept painted in conspicuous characters on every storage vessel containing petroleum, the description of petroleum, with the addition of the words "highly inflammable."

7. That petroleum be only conveyed to or from the licensed premises in closed vessels, so constructed as to be entirely free from leakage.

8. That no petroleum be conveyed to or from the licensed premises in a vehicle in which gunpowder or other article likely to cause fire or explosion is also carried.

9. That petroleum be only received in or supplied from the licensed premises between sunrise and sunset; and that no artificial light or fire, or article likely to cause fire, be at any time taken into or near the place of storage.

10. That the vessels containing petroleum be only opened upon the licensed premises at or immediately adjoining the place of storage, and for the time necessary for drawing off the petroleum, and that during such drawing off every reasonable precaution be adopted for preventing the escape of petroleum or the vapour therefrom.

11. That all petroleum received upon the premises be at once taken to the place of storage; and that petroleum taken from the place of storage for delivery or otherwise, be at once removed from the premises.

12. That the licensee do take effectual precautions for preventing unauthorised persons and all persons under the age of 15 years from obtaining access to the place of storage.

13. That not less than bushel of sand be kept with every vessel in which petroleum is stored, and that some portion of this be constantly kept immediately under the tap of the vessel.

14. That due precaution be at all times taken for the prevention of accident from fire.

15. That every authorised Officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do, by himself or his representatives, give any assistance for that purpose which such Officer may require.

By Order of the Council,

Clerk of the Council.

(Section 9 of the Petroleum Act, 1871, provides that "any licensee violating any of the conditions of his license shall be deemed to be an unlicensed person.")

This license is not transferable.

REGULATIONS AS TO LABELLING VESSEL CONTAINING PETROLEUM.

Section 6 of the Petroleum Act, 1871, provides that where any petroleum to which this Act applies:—

(The section referred to, see p. 737, is appended to the form of license.)

LONDON COUNTY COUNCIL.

Special License.

(No. 2.)

Petroleum Acts, 1871 *to* 1881.

Reg. No.

PETROLEUM LICENSE.

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, the London County Council doth hereby, at the request of grant License to for the period of twelve calendar months from the to keep gallons of Petroleum to which the Acts apply, and as defined in the said Acts, on the premises, in the parish of and within the jurisdiction of the said Council, subject to the conditions following, that is to say—

That no fire, or any such artificial light as would ignite inflammable vapour, be kept at any time within or nearer than feet of the openings of buildings where petroleum is kept.

That vessels containing petroleum be only opened for the time absolutely necessary for the purposes of the business, and that every precaution be used for preventing the inflammable vapour from escaping from such vessels.

That due precaution be at all times taken for the prevention of accident from fire.

That every authorised Officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do, by himself or his representatives, give any assistance for that purpose which such Officer may require.

By Order of the Council,

Clerk of the Council.

(Section 9 of the Petroleum Act, 1871, provides that any "licensee violating any of the conditions of his license shall be deemed to be an unlicensed person.")

This license is not transferable.

Special license.

(No. 3).

Reg. No.

LONDON COUNTY COUNCIL.

Petroleum Acts, 1871 *to* 1881.

PETROLEUM LICENSE.

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, the London County Council doth hereby, at the request of , grant License to , for the period of twelve calendar months from the to keep gallons of petroleum to which the Acts apply, and as defined in the said Acts, on the premises in the parish of and within the jurisdiction of the said Council, subject to the conditions following, that is to say—

That the petroleum be kept only in a strong metal vessel fitted with a screw cap, and with a screw tap in

That the workroom be at all times thoroughly ventilated into the external atmosphere.

That not less than 1 bushel of sand be kept in the workroom.

That no fire, or any such artificial light as would ignite inflammable vapour, be at any time within or nearer than feet of the place where petroleum is kept.

That vessels containing petroleum be only opened for the time absolutely necessary for the purposes of the business, and that every precaution be used for preventing the inflammable vapour from escaping from such vessels.

That due precaution be at all times taken for the prevention of accident from fire.

That every authorised officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do, by himself or his representatives, give any assistance for that purpose which such officer may require.

By order of the Council,

Clerk of the Council.

Section 9 of the Petroleum Act, 1871, provides that any "licensee violating any of the conditions of his license, shall be deemed to be an unlicensed person."

This license is not transferable.

LONDON COUNTY COUNCIL.

PUBLIC CONTROL DEPARTMENT,
21 WHITEHALL PLACE, S.W.,
July, 1893.

PETROLEUM LAMPS.

In view of the numerous fatal and other accidents caused by petroleum lamps, the Council considers it desirable to make public the following suggestions, which are partly founded on recommendations made by Sir FREDERICK ABEL, C.B., D.C.L., F.R.S., *and* Mr. BOVERTON REDWOOD, F.I.C., F.C.S., *after investigating the causes of lamp accidents.*

SUGGESTIONS AS TO THE CONSTRUCTION AND MANAGEMENT OF PETROLEUM (OR PARAFFIN) LAMPS.

Construction of Lamps.

1. The wick should be enclosed in a tube of thin sheet metal, open at the bottom. This wick tube should reach almost to the bottom of the reservoir containing the oil.

2. The oil reservoir should be of metal, and not of china, glass, or other fragile material.

3. The upper part of the lamp which comprises the burner, wick-tube, &c., should be constructed to securely screw into the metal reservoir.

4. The oil reservoir should have no feeding-place nor opening, other than the opening into which the upper part of the lamp is screwed.

5. Every lamp should have a broad and heavy base, and a proper extinguishing apparatus.

Wicks.

6. Wicks should be soft, and not tightly plaited, and should quite fill the wick-holder without having to be squeezed into it.

7. Wicks should be dried at the fire before being put into lamps, and should be soaked with oil before being lit.

Management.

8. The reservoir should be quite filled with oil every time before using the lamp.

9. The lamp should be kept thoroughly clean, all oil should be carefully wiped off, and all charred wick and dirt removed before lighting.

10. When first lit, the wick should be partially turned down, and then slowly raised.

11. Lamps which have no extinguishing apparatus should be put out as follows:—The wick should be turned down until there is only a small flickering flame, and a sharp puff of breath should then be sent across the top of the chimney, but not down it.

12. Cans or bottles used for oil should be free from water and dirt, and should be kept thoroughly closed.

ALFRED SPENCER,
Chief Officer.

NOTE.—These suggestions apply to ordinary petroleum or paraffin lamps such as are generally used, and not to benzoline or spirit lamps.

The following are bye-laws of the Conservators of the River Thames, bye-laws of the Mersey Docks and Harbour Board, and regulations of the Bristol Docks Committee, relative to petroleum imported into London, Liverpool, and Bristol respectively:—

RIVER THAMES.

BYE-LAWS UNDER THE PETROLEUM ACTS, 1871 & 1879.

The Conservators of the River Thames, in exercise of the powers vested in them by "The Petroleum Act, 1871," and "The Petroleum Act, 1879," and of every other authority them hereunto enabling, do order and direct as follows:—

1. The bye-laws for the regulating of the carriage of petroleum in the River Thames, confirmed by the Board of Trade on the 13th day of July, 1872, shall, after these present bye-laws have been confirmed by the Board of Trade, be, and the same are hereby repealed.

2. No ship or vessel laden either wholly or in part with petroleum, rock oil, Rangoon oil, Burmah oil, or oil made from petroleum, coal, schist, shale, peat, or other bituminous substance, or any products of petroleum, or of any of the above-mentioned oils, which said oils or products of oils, when tested in manner set forth in Schedule I. to "The Petroleum Act, 1879," give off an inflammable vapour at a temperature of less than 73 degrees of Fahrenheit's thermometer, shall for any purpose whatever be navigated, lie in, or be moored, and no part of the cargo shall be discharged from any such ship or vessel in any part of the River Thames, above or westward of Thames Haven; and all such ships or vessels whilst laden as aforesaid shall, when moored or anchored, lie singly and apart from each other. with a clear space of not less than 100 feet of water separating them.

3. All fires and lights shall be extinguished on board ships and vessels during the time the petroleum, defined in bye-law No. 2, is being laden or unladen, or when the hatches covering the place where the petroleum is stowed are open.

4. The cargoes of such ships or vessels may be discharged below Thames Haven into barges licensed for the purpose by the Conservators of the River Thames.

The petroleum when on board such barges shall be so covered as to prevent the risk of sparks falling upon or among the casks.

No fires or lights shall be used upon such barges when either laden or partly laden with petroleum, and the barges shall be towed to their places of destination only during daylight.

The petroleum shall only be landed at wharves or other places now or hereafter licensed by the local authority.

5. Where any ship or cargo is moored, landed, towed or otherwise dealt with in contravention of any of the foregoing bye-laws, the owner or master of such ship, or the owner of such cargo, both or either as the case may be, shall severally incur a penalty not exceeding £50 for each day during which such contravention continues; and it shall be lawful for the Harbour Master, or any other person acting under the orders of the Conservators of the River Thames, to cause such ship or cargo to be removed, at the expense of the owners thereof, to some place at or below Thames Haven, and all expenses in or incident to such removal may be recovered in the same manner in which penalties are by "The Petroleum Act, 1871," made recoverable.

Given under our Common Seal this 1st day of March, 1880.

Seal

E. Burstal,
Secretary.

The Board of Trade hereby signify their confirmation of the above bye-laws.

By order of the Board of Trade, the 12th day of April, 1880.

C. Cecil Trevor,
Assistant Secretary.

Mersey Docks and Harbour Board.

The present Bye-Laws, made pursuant to the 4th Section of the Petroleum Act of 1871, and the Mersey Dock Acts Consolidation Act, 1858, were sealed by the Board, June 14, 1878.

These Bye-Laws contain the following definitions:—

"*Dangerous petroleum*" shall include all such petroleum, and all such oil derived from petroleum, coal, schist, shale, peat, or other bituminous substance, and any product of petroleum, or any of the oils above-mentioned that give off an inflammable vapour at a temperature of less than 100° of Fahrenheit's thermometer, when tested in the manner set forth in the schedule to "The Petroleum Act, 1871."

"*Common petroleum*" shall include all such petroleum, oil, and products of petroleum or oil as above-mentioned that does not give off an inflammable vapour at a temperature of less than 100° of Fahrenheit's thermometer, when tested in the manner above-mentioned.

Vessels containing petroleum of any kind as cargo are prohibited from entering any other docks than those adjoining the quays where the landing of petroleum is permitted under the bye-laws, and the limits of mooring in the River Mersey, for vessels carrying over 200 gallons of "dangerous petroleum," are fixed as northward of a line from Victoria Tower to Egremont Ferry, or south of a line between New Ferry Pier and Dingle Point.

The landing-places for petroleum may be changed by resolution of the Board.

The landing of "dangerous petroleum" must be effected between 6 a.m. and 6 p.m. from March to September inclusive, and between 8 a.m. and 4 p.m. from October to February. No fires, lights, or matches, other than safety-matches, may be used either on such vessels, or on the quays where the oil is being landed or stored, and both ships and quays must be under the supervision of a competent watchman. The same regulations apply also to the loading of vessels with "dangerous petroleum." During the loading of vessels containing over 200 gallons of such oil, and their stay in dock—which, however, must in no case exceed twenty-four hours—a police constable must be present. Steamers about to leave dock are allowed to use such fires and lights as may be necessary, for four hours before leaving. All casks containing "dangerous petroleum" brought to, or placed on any quay for shipment, must be distinctly marked as dangerous.

Bristol Docks Committee.

REGULATIONS FOR THE DISCHARGE AT AVONMOUTH DOCK OF PETROLEUM IN BULK

To which the Petroleum Acts, 1871 *and* 1879, *do not apply.*

1. Previous to the discharge of any petroleum, a certificate must be produced by the importer stating that the oil does not flash under 73° F., and if possible, also stating the temperature at which it does flash.

2. An application in writing must be made by the importer to the Harbour Master for permission to pump the oil from the vessel into the pipes leading to the storage tanks, or into tanks placed on the quay, and the applicant must indemnify the Corporation of Bristol against all losses, damages, costs, or expenses which they may incur or become liable for by reason of the granting of any such permission. No oil shall be allowed under any circumstances to leak or flow into the dock, or on to the quay.

3. No fires or lights shall be allowed on board the vessel during the time of discharging, except such necessary fires in the engine-room for generating steam for pumping the oil as the Harbour Master may from time to time permit; and no smoking shall be allowed on board the vessel, or any lighter lying alongside, or on the quay during such time.

4. Every possible precaution must be taken, both by the master of the vessel and by the importer, to prevent risk of fire or explosion; and also to prevent any oil being spilled on the quay, or leaking or flowing into the dock. Notice in writing must be given by the master of the vessel to the Harbour Master previous to water being pumped into the tanks of the vessel.

5. The vessel shall not, whilst in the dock, be left without a sufficient crew on board. No persons, other than the crew and such other persons as shall be employed or engaged by the importer, or by the master or owner of the vessel in connection with the discharge of the cargo, shall be allowed on board the vessel or on the quay alongside.

6. For the safer discharge of the cargo, an officer will be sent by the Harbour Master to superintend the carrying into effect of these regulations, payment being made of the expense of such superintendence by the master or owner of the vessel; and the payment of such expense of superintendence shall continue until the production to the Harbour Master of a certificate under the hand of such officer that the cargo has been duly discharged.

7. An application in writing must be made to the Harbour Master for permission

to ventilate the tanks after the oil has been pumped therefrom, an intimation being given at the same time as to the mode in which it is proposed to effect such ventilation; and the Harbour Master may, in his discretion, either withhold or grant such permission, and subject to such special regulations and arrangements as he may deem necessary.

8. No lighter or other craft shall, except with the permission of the Harbour Master, lie alongside any vessel during the discharge of her cargo.

9. Every vessel having petroleum on board shall keep conspicuously exhibited from sunrise to sunset a red flag.

By Order of the Docks Committee,

F. B. GIRDLESTONE,
Secretary and General Manager.

DOCKS OFFICE, QUEEN SQUARE,
1st May, 1890.

COLONIAL AND FOREIGN.

ANTIGUA.

Gunpowder and Petroleum Acts:—No. 12, 1874; No. 9, 1889; No. 9, 1890; read together.

The first of the above Acts empowered the Governor to appoint a fitting place beyond the limits of the City of St. John as a petroleum store, and prohibited storage elsewhere, except for private use (with a limit of 10 gallons), or for retail sale (with a limit of 20 gallons, increased by the 1889 Act to 96 gallons). Licenses for sale (retail) to be granted by the Treasurer, for terms of three months, subject to a stamp duty of 1s. A standard of test was introduced by the Act of 1889, the minimum fixed being 83° F. (Abel test). All oils flashing below the standard are classed as "volatile petroleum," and their importation is prohibited under penalty of forfeiture and fine, unless the importer furnishes proof of ignorance of their low-test quality (when re-shipment is allowed), an exception being made in favour of oil not intended for burning, if kept in closed glass bottles of a capacity not exceeding 8 ozs., and of gasoline (Act of 1890) for use in scientific or technical work, or in the Government Laboratory, under permission from the Governor. Three samples must be furnished by importer for testing by the Government Analyst or other appointed person before the oil is landed, and samples may be drawn by the Treasurer from oils in store for re-testing at any time.

AUSTRALIAN COLONIES.

NEW SOUTH WALES.

Kerosene Act, 1871, 35 Vict., No. I.

This Act prohibits the sale of any kerosene giving off inflammable vapour below 110° F., unless the vessel containing it is legibly labelled "dangerous," and bears a caution against bringing any light near to it.

Importers and refiners are to give notice to the inspector, and no oil is to be delivered without the inspector's certificate. Not more than 200 gallons may be stored within 50 yards of another house or warehouse within the boundaries of a town or municipality, except on premises where it is manufactured, in which case an unlimited quantity may be stored. Inspector may search, under warrant, all suspected places, and may inspect all stores and test the oil offered for sale. Such oil as may thus be found below test is liable to confiscation. Appeal against inspector's test is to be decided by reference to a competent person appointed by the Justices.

Testing.—The instrument directed to be used is described as the "Metropolitan Petroleum Oil-tester of W. C. Miles, 36 Gt. Pearl St., London, as used by the Metropolitan Board of Works." The test is to be carried out in a closed room free from air currents. The water bath is to contain 16 ozs. by measure of water at not less than 70° F., and the oil cup 2 ozs. by measure of oil. The bulb of the thermometer is to be half an inch below the surface of the oil. The test-flame is to be applied by drawing it along the wire over the surface of the oil at every 5° or less, at the discretion of the operator, until 90° F. is registered, thence, up to 100°, at every 2°, and over 100°, at each 1° rise, until the oil flashes; 110° being the standard, and the time occupied in the operation not exceeding fifteen minutes from the immersion of the oil cup in the water bath.

QUEENSLAND.

Mineral Oils Act, 188C.

The importation into Queensland, for lighting purposes, of all refined mineral oils flashing below 110° F., open test, or 83° F., close test, is prohibited, and any oil so imported may be confiscated and destroyed. The Act does not apply to oils other than for lighting. Customs officers or other authorised persons may inspect and sample for testing, and if the testing officer finds that any oil fails to pass the test, such oil is liable to confiscation, but the Governor may instead allow the oil to be re-shipped, subject to the packages being legibly marked in 2-inch letters—"Under test." Any appeal against the inspector's test must be made within fourteen days, and decided by an expert. Obstruction of inspector is punishable by fine.

Test.—Open test—Same as specified in English Act, 1871. Close test—Abel instrument.

Directions for Close Test.—The apparatus must not be exposed to draughts. The water in the bath must be at 130° F. at the commencement of the test, when the oil cup containing the sample to be tested (cooled to about 70° F.) is placed in the bath, the lid of the cup being on, and the slide closed. At 76° F., the testing is to be commenced, and the application of the test-flame is to take place at every 1° rise. During hot weather, if a sample flashes below 83°, the test must be repeated with the oil cooled to 63°, the flame being first applied at 68° F. The flashing point thus obtained is to be regarded as the true one.

SOUTH AUSTRALIA.

Kerosene Storage Acts, 1873 (37 *Vict. No.* 11) *and* 1874 (37 *and* 38 *Vict. No.* 23).

Under the definition of "Kerosene," all the usual products specified in Petroleum Acts are included, but *without any limit of flashing point*, and there are no testing regulations. Ships carrying over 200 gallons, coming within 500 yards of a wharf, shall land the excess within seven days, unless having at least 50 tons of other cargo on board, when nine days are allowed. This limit may be extended for three days, by permission of the chief Secretary. The landing must take place between sunrise and sunset, and the oil be removed from the wharf during that time, any remaining after sunset being seizable. The Act does not apply to private landing places outside a municipality. Vessels taking in more than 200 gallons for export must remove to a distance of 500 yards from the wharf within nine days. Regulations for loading, &c., are under control of the Governor.

Storage.—50 gallons allowed for private consumption. From 50 to 500 gallons may be stored below the level of the ground in any house, warehouse, store, shop, shed, building, cellar, yard, excavation, or other place within a municipality or within 500 yards of the boundary thereof, without license, if adequate ventilation is provided. Smoking and the use of matches or lights in any kerosene store, other than a store for private consumption, are prohibited. Inspectors have power of search, and resistance to inspectors is punishable by fine.

VICTORIA.

Customs Consolidation Acts, 1883 *and* 1890 (*Sections* 50 *and* 51).

The importation into this colony, of refined mineral oils or "painters spirits," which give off inflammable vapour at temperatures below 100° F., on being subjected to the test prescribed in the 4th Schedule by any officer or person duly authorised by the Collector of Customs, is prohibited. Low-test oils may, however, be imported, or delivered by the Customs Department on payment of the duty chargeable thereon, provided they have been duly coloured by the admixture of such material and in such proportion as the Governor in Council may prescribe, and that any package containing such oil shall have distinctly marked on the side or top thereof in black Roman letters of not less than 2 inches in length and half an inch in breadth, the words "specially dangerous." The penalty for removing the said mark or selling such oil without mark, is a fine of £100 and forfeiture of the oil. Customs officers, or other persons duly authorised by the Collector of Customs, may enter stores, &c., and draw samples for testing.

Testing.—The apparatus is that prescribed in the English Act of 1871 (34 and 35 Vict. c. 105, Sched. 1) (see p. 550). The first test is applied at 90° and is repeated at every 2° to 3° rise. The confirmatory test is applied at intervals of 2°.

WEST AUSTRALIA.

Explosives Act, 1885.

In this Act, "Petroleum" includes all kerosene, rock oil, Burmah oil, Rangoon oil, or any product of them, and any oil made from petroleum, coal, schist, shale, peat, or other bituminous substance, or any produce of them giving off inflammable vapour below 110° F. (open test). All mineral oils imported into the Colony must be examined immediately on arrival, before delivery to the owners or consignees. Inspectors have right of entry to every ship in which mineral oils are imported, and any obstruction by captain or other person is punishable by fine. Oils failing to pass the test shall, if landed, and on satisfactory proof of their character being given before two Justices, be liable to be forfeited and destroyed. In case of dispute as to the test, the Justices shall allow a further test to be made, and shall then decide. **Storage** is dealt with by the Act of 4th August, 1871 (35 Vict., No. 5). The Governor in Council may make harbour regulations affecting vessels carrying petroleum. Within 50 yards of a dwelling-house or warehouse, "petroleum" must not be kept, otherwise than for private use, and then only in quantities not exceeding 10 gallons, except under license from the local authority, and in granting such license, the authority may impose conditions of storage. Inspectors have right of search, on suspected premises, for oils stored contrary to the provisions of the Act.

Testing.—The description of the instrument, and of the mode of testing, is the same as that given in the schedule of the English Petroleum Act, 1871.

NEW ZEALAND.

As far back as 1863, there was a local *Kerosene and Paraffin Oil Ordinance* for the province of Otago, amended in 1868 by the *Inflammable Oils Ordinance.* It included "kerosene" and "paraffin oil," and "benzine," without any regard to test, and limited the storage in Dunedin and other towns—otherwise than under license from the Superintendent of the Province, or in the Petroleum Warehouse—to 64 gallons in the case of dealers, and 16 gallons for private consumption, imposing penalties for infraction, of £20, and 5s. for each gallon of oil in excess of the quantity allowed, the maximum fine being £100. 300 gallons was allowed under license. Justices of the Peace were empowered to issue warrants for searching suspected premises, and all oil stored in contravention of the Ordinance was forfeitable.

The present regulations, which apply to the whole colony, are contained in the *Dangerous Goods Acts of* 1869 *and* 1878. The standard flashing point (open test) is fixed at 110° F., and the directions for testing are similar to those in Victoria. No low-test oil may be offered for sale unless marked "Dangerous—no light to be brought near." The Governor may at any time bring oils which are not below test, under the operation of the Act, by an order in Council, applying to any portion or the whole of the colony. Vessels carrying petroleum must conform to such regulations for mooring, &c., as the Governor may make by order in Council. No "petroleum," except such as is kept solely for private use, and then only in quantities not exceeding 10 gallons, may be stored within 50 yards of a dwelling-house or building in which goods are stored, unless under license, granted by the Local Authority. In such license, the conditions of storage may be prescribed. The applicant may appeal to the Colonial Secretary against any refusal of the Local Authority to grant a license, or if he is dissatisfied with the conditions imposed. Inspectors are appointed by the Local Authority, and police officers are empowered to inspect oil stores during the day-time, and demand samples for testing (which must be paid for). In case the oil does not conform to the provisions of the Act, the offender is liable to a fine of £5. If he appeals against the test, the Magistrates can order a re-test by a competent person, the cost to follow the result. Searching suspected premises under warrant is provided for, and obstruction of inspectors is punishable by fine.

TASMANIA.

39 *Vict.*, *No.* 9, "*an Act to place certain restrictions on the storage of kerosene*," 30*th September*, 1875.

This statute authorises the Governor to appoint storage places near Hobart Town and Launceston, to appoint keepers of the said stores, and to fix the charges to be paid for storage. The power of making regulations as to the time and mode of reception and delivery of kerosene, which includes "all paraffin, gasoline, and all rock oil, or any product thereof, as well as any oil made from petroleum, kerosene, coal, schist, shale, peat, or other bituminous substance, or any product thereof" is also vested in the Governor. The limit of quantity to be stored "in or upon any house, storehouse, warehouse, shop, cellar, yard, wharf, or any other building or place within the boundaries of either town" is fixed at 200 gallons, unless the store is over 50 yards distant from a dwelling-house or building in which goods are stored. Infraction of this is punishable by forfeiture of the oil, and a fine.

AUSTRIA.

Law of 4th July, 1865.

The law extends to all natural and artificial mineral oils. A license is necessary for the retail sale. No mineral oil may be sold for illuminating purposes which has a flashing point below 30° Réaumur (= 100° F.), *open test*. The quantity of oil not suitable for illuminating purposes (*i.e.*, below 30° Réaumur, open test) which may be kept in a house, may not exceed 5 cwts., and then only in vessels not admitting of evaporation or leakage. The premises must be fireproof and so constructed that, in case of fire, air can be entirely excluded. Only safety-lamps are allowed. Smoking is forbidden. The same limit is imposed with regard to illuminating oils, except that it is open to the local authority to extend the quantity by special permission, if no liquid under the standard test is present, and provided that the oil be kept in well closed and perfectly tight casks. Where the quantity exceeds what may be kept in an inhabited house, it must be kept in an uninhabited building at such distance from any inhabited building as the local authority may consider necessary. The building is to be fireproof and so constructed as to allow of air being excluded in case of fire. Safety-lamps only are allowed; smoking is prohibited. There are regulations as to carriage, &c. Wholesale storage is almost entirely carried on by the railway companies.

TRIESTE.

Regulations of the Petroleum Harbour at S. Sabbia, 1891.—The control of the petroleum harbour at S. Sabbia is vested in the officials of the port, except in so far as concerns the State railway or other department of the State. The police and other arrangements at the goods yard are under the control of the railway officials. Tank steamers have precedence over all other vessels for stations in the harbour, and rank amongst themselves in the order of their arrival. Sailing vessels or other steamers, lying at the wharf for loading or unloading barrels or cases, must give place to tank steamers when required. Vessels must be so moored that they can be cast loose. No reduction may be made in the number of hands on board until unloading is completed and the vessel has left her moorings. Tank steamers may use steam pumps, worked by steam from the boilers, for unloading; other steamers may use cranes or winches for the same purpose, provided the boiler for generating the steam is in the usual boiler room. The only light allowed on board petroleum vessels, is that approved by the harbour authorities. On steamers, a lamp is allowed in the galley, and cooking may be done on board if water is kept at hand for use in case of fire; but for sailing vessels, the cooking must be done on shore in an appointed spot, unless the harbour officials are satisfied that it may be safely conducted on board. No stoves may be lighted so long as the vessel remains alongside the wharf. Smoking is forbidden, both on board and within the limits of the petroleum stores on shore. Unloading or loading must proceed at the rate of 400 barrels, at least, per diem, Sundays, holidays, and bad weather excepted. For this purpose, 5 cases are considered as the equivalent of 1 barrel. The oil must be taken away by the consignees as it is landed. Admission to the petroleum stores is only allowed under special permission in the case of private persons not working therein. Foremen must be provided to superintend by day and night, and it is part of the foreman's duty to see, after the cessation of work for the day, that all lights and fires are properly extinguished. Pumping out steamer tanks between sunset and sunrise, is only allowed in exceptional cases and by the special permission of the harbour authorities, and similar permission is necessary for the filling of tank-cars, barrels, or cases. The storage of full or empty cases or barrels, or of easily inflammable substances, in the open, is forbidden. In sheds and boiler-houses, a supply of water must be kept at hand, in case of fire, together with hand pumps strong enough to force a jet up to the ceiling. No fuel or inflammable substances may be placed on boilers or near the fire doors. So long as the boiler is in use, a qualified person must be present in the boiler-room, and the pumps and boilers may only be left unattended when all fires and lights are extinguished. The soldering of petroleum tins may only be effected in a place set apart by the authorities, containing a plentiful supply of sand or ashes and shovels ready to hand. No open light is allowed in the precincts of the stores, nor are petroleum lamps allowed in closed rooms.

Regulations of the Captain of the Port, 15th May, 1879.—Petroleum may be loaded in small quantities, and under the supervision of the harbour authorities, into lighters in the old port. Such boats, having petroleum on board, must remove from the shore at sundown, or, if prevented by bad weather from so doing, must be guarded by a watchman. No fires, open lights, or smoking, allowed while petroleum is on board. All petroleum lying on the quay, waiting to be loaded, must be under guard, but can only be allowed to so remain under exceptional circumstances. Steamers of the Austro-Hungarian Lloyd Co., lying at the quays, are allowed to take petroleum on board, provided this is effected on the day of departure and completed by sunset, and that the vessel is under the surveillance of two watchmen, as in the case of lighters detained at the quay.

Storage.—Storekeepers must observe all the general regulations governing the sale of combustibles. No petroleum may be stored in a retail shop. A specially constructed metallic vessel, sufficient to hold about a barrel, must be provided for storage, and this must be enclosed in a pit lined with brick, the roof being arched and covered with a paving stone. Through a hole in the cover projects a metal filling pipe, well soldered to the vessel, and provided with a screw stopper. The space between the bottom of the storage receptacle and the flooring of the pit, must be filled with sand to absorb outflow of oil. The storage of empty cases or barrels in retail shops is prohibited.

BAHAMAS.

Apparently no regulations.

BARBADOS.

Petroleum Act, 1882, *and Amendment,* 1892.

The standard test is 83° F. (Abel instrument). Any oil flashing below this point, is termed "volatile petroleum." All wholesale storage of petroleum must take place in the Government warehouse. For retail purposes, 200 gallons in metal vessels, or 50 gallons in wooden vessels, may be kept in a shop or store. No "volatile petroleum" may be imported under penalty of forfeiture. Comptroller of Customs draws samples of cargo, which are tested by the Professor of Chemistry. Provision is made for re-testing, in case the owner objects to the result of the test.

BELGIUM.

The regulations are local only.

ANTWERP.

The quantity of oil to be kept by retailers, is limited to two barrels.

BERMUDA.

Petroleum Act, 1887.

The Act applies to petroleum giving off an inflammable vapour at less than 73° F. (method of testing not specified, but it is presumably the Abel test), and chiefly relates to harbour regulations for import vessels. No low-test oil may be kept without license, otherwise than to the extent of 3 gallons in separate well-stoppered vessels holding not more than 1 pint. These vessels are to be labelled "highly inflammable," and to bear owner's, sender's, or vendor's name. Licenses are under the control of the Governor. Fraudulent importation, or sale, of low-test oil is punishable by penalty.

BRITISH BALUCHISTAN AND BRITISH BURMA.

The *Petroleum Acts of India* (*q.v.*) apply.

BRITISH GUIANA.

By the *Petroleum Ordinance* (*No.* 14), 1872, power was vested in the Governor in Council, to make regulations for the storage of petroleum and its products, but does not appear to have been exercised.

The *Tax Ordinance of* 1865 *and that* (*No.* 3) *of* 1881 fixed the duty on "oils which give off an inflammable vapour at a temperature of less than 130° F." at $3 per gallon, all other oils paying only 15 cents duty, without specifying how the test should be applied, the object of the differential duty being apparently to discourage the importation of low-test oil. In December, 1881, the Governor authorised the admission of oils testing 110° F. on payment of 15 cents duty in cash and $2.85 by note "only to be collected in the event of the Combined Court refusing to refund such amount of duty." The existing standard of test is 73° F. (Abel), the duty being 18½ cents per gallon, gasoline (when admitted by consent of the Governor and Court of Policy) paying 25 cents. All other low-test oils pay $3, except those from the United States, which, by agreement between the two Governments, are only charged $2.25 per gallon. These regulations are laid down by the *Customs Ordinance* (*No.* 2) *of* 1892.

BRITISH HONDURAS.

Dangerous Goods Ordinance, No. 10, *of* 1878.

Standard 100° F. (open test) flashing point.

Limit of quantity to be stored without license, 10 gallons (and this only for private use), unless 50 yards distant from a dwelling-house or store. Conditions of license are left to the local authority. Provision is made for the appointment of inspectors for testing, and for searching suspected premises.

CANADA.

PETROLEUM INSPECTION ACTS.

Revised Statutes of Canada, 49 *Vict.*, 1886, *c.* 102; *Petroleum* (*Inspection*) *Act*, 56 *Vict.*, 1893, *c.* 36; *Petroleum* (*Inspection*) *Act Amendment*, 57 *and* 58 *Vict.*, 1894, *c.* 40.

In the first-named Act, "petroleum" is defined as refined mineral oils and their products weighing not less than 7·75 lbs. per gallon at 62° F. and 30 inches barometric pressure, and "naphtha" as all such oils weighing less than the amount stated. The flashing point was at first fixed at 95° F., close test, and no oil failing to pass this test, or weighing more than 8·05 lbs. or less than 7·75 lbs. per gallon, was allowed to be sold for illuminating purposes, except for burning as vapour in street lamps, or in premises where it could be vaporised in underground tanks external to the building, or for technical or chemical purposes in buildings other than dwellings (*Sect.* 5).

"High-test oil," weighing between 8·23 and 8·32 lbs. per gallon, and firing at 295° F., or flashing at 250° F., open test, was permitted to be sold for burning, provided the packages were branded as such, together with the weight per gallon and the test.

In consequence of an agitation against the high standard of flashing point, a reduction was made in 1893, to 90° F. for ordinary illuminating oil, whilst the weight and test for the "high-test oils" were changed to 8·14 to 8·43 lbs. per gallon, and 200° F. fire test, or 180° F. flash test. This reduction not being regarded as sufficient, an amending Act passed in 1894 substituted a standard flashing point of 85° F. for the one previously in force. The regulation of the standard of density for "high-test oil" was at the same time vested in the Inland Revenue Department, and the employment of "composite high-test oil" of a minimum flashing point of 145° F., "for outside service only," was allowed under restrictions as to specific gravity to be prescribed by departmental regulations.

All packages containing Canadian petroleum must be branded by the refiner, or his agent, with the flashing point, weight per gallon, gross and nett weights, tare (in lbs.), number of gallons, date of filling, and name of refiner or packer, and must be inspected before leaving the premises. In the case of imported petroleum, the inspector who tests it shall brand each package with the flashing point, and weight per gallon, and shall also mark it with his name and the date of inspection. Naphtha shall be branded as such, instead of the packages being branded with the flashing point. Canadian petroleum may be removed under permit, without inspection, for completion of manufacture, or in order that it may be packed, and may also be exported without inspection, but if offered for sale in Canada uninspected, it becomes liable to confiscation. Imported petroleum (other than lubricating oil) not conforming to the Act, must be branded "rejected," and will be forfeited if not re-exported within ten days. For testing, one sample must be drawn from every 10 packages, two being the minimum. Inspectors may enter refineries or stores during business hours for inspecting and sampling petroleum and naphtha, and may take samples from hawkers or other persons offering these liquids for sale. In case of dispute as to test, the decision of the Department of Inland Revenue at Ottawa shall be final. Penalties are incurred by keeping petroleum or naphtha in unmarked packages, or not in conformity with the marks on the packages; for altering, counterfeiting, or improperly using inspectors' brands; substituting inferior oils for the contents of tested vessels; and by an inspector, for allowing fraudulent use to be made of his brands or giving a false certificate; also by any one assuming the title and office of inspector without due authority.

Storage is regulated by orders of Governor in Council, no person being allowed to import or store petroleum or naphtha without a permit from the Minister of Inland Revenue. All imported naphtha and petroleum must be in packages of not more than 50 gallons[1] each, and must be entered only at Customs ports specified by Governor in Council, who may likewise designate places where petroleum for illuminating purposes may be imported in tank cars under joint regulations of Customs and Inland Revenue Departments, but such petroleum must be put into packages, inspected and marked, in the manner already specified, before removal for consumption. Oils intended solely for lubricating, and unfit from their nature for illuminating, shall, if branded "non-illuminating," be exempted from the provisions of the Act with regard to inspection. The Abel apparatus is used in testing.

Storage (*Order in Council of* 9*th January*, 1889).—Where there are municipal laws respecting petroleum storage, inspected oil may be kept in accordance therewith. In all other places, petroleum or naphtha, if exceeding two barrels of refined petroleum or 10 gallons of naphtha, must be stored under naphtha license from the Inland Revenue Department in isolated premises at least 100 yards from the nearest building not owned or occupied by the storer, and only under the conditions of sect. 5 of the "Petroleum Inspection Act, 1886." With regard to the seizure of low-test oil, if the quantity exceeds ten barrels, it may, after being branded as naphtha, be returned to the owner, on payment of the money penalty imposed by the Act, and on condition that it is refined to standard test oil. This, however, applies to a first offence only; in all other cases, the seizing officer may sell the oil at a fair value for rectification, the money being forfeited. Quantities of less than ten barrels may be dealt with in the same way, or sold to be stored under the conditions and regulations affecting naphtha. An order in Council, dated 6th June, 1892, allows storage of naphtha for use in "naphtha launches," in addition to the purposes specified in Sec. 5 of the Act of 1886. The amending Act of 1894 authorises the Inland Revenue Department to allow storage in metal tanks, subject to this Act, and the regulations made thereunder.

City of Quebec (1866).—A license is required. Quantities exceeding five barrels must be kept in a building or place not less than 100 feet from any other building, and separated therefrom by a wall of masonry 10 feet high and 12 inches thick. In the absence of such a protecting wall, the intervening distance from other buildings must be increased to 300 feet. In such cases, the limit of quantity, if any, would appear to be regulated by the license. Up to the five-barrel limit, the oil must be kept in well closed iron tanks, or in isolated stores or buildings, well ventilated, and expressly adapted for that purpose by means of elevated sides, so as to effectually prevent the overflow or escape of their contents. Full powers of inspection are conferred on the officers appointed by the Council.

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[1] The Act of 1894 sanctions the importation under departmental regulations (not detailed) of gasoline and naphtha in iron drums holding up to 120 gallons.

City of Toronto.—Within certain specified areas, no more than ten barrels may be kept, except in a fire-proof building, thoroughly ventilated and isolated, or detached 25 feet from any other building (or 100 feet, where mineral spirit is stored). Outside this district, the foregoing restriction applies only to mineral spirit, and not to refined petroleum. In all cases, the place of storage must be licensed, the control being vested in the Standing Committee on fire, water, and gas.

CAPE COLONY.

There is no general law in Cape Colony relating to the importation and storage of mineral oils. The only regulations on the subject in the Colony, are those framed by the local authorities. These specify the quantity that may be stored in premises without license. The limit varies considerably, being only 20 gallons in some places, while in others it is as much as 100 gallons.

CEYLON.

Petroleum Ordinance, 1887.

"Dangerous" petroleum is defined as flashing below 76° F. (Abel test), a margin of 3° being allowed where a cargo is declared to be of uniform quality (the samples tested must average 73° flashing point, and none must be below 70°). Lubricating oil flashing at over 200° F. is exempted. More than 3 gallons of "dangerous" petroleum cannot be imported or stored without license, unless kept in separate vessels, securely stopped, and holding not more than 1 pint. Applications for licenses must specify quantity to be stored, nature of premises, and description of storage vessels; must set forth the purpose for which the petroleum will be used; and must declare that only "dangerous" petroleum can be employed for that purpose. Vessels must be labelled "highly inflammable," and must bear a description of the contents (in English, Cingalese, and Tamil), together with the name of the consignee, sender, or vendor. The Governor may specify the ports at which petroleum can be admitted, and may make regulations for discharging and storing; he may also fix the number of samples to be tested, and arrange for the re-testing and division of cargoes lacking uniformity. No quantity of petroleum exceeding 50 gallons may be kept, except under license from the Local Authority. Hawking is regulated by provisions similar to those of the English Act of 1881, the limit of quantity for each carriage being 24 gallons. Penalties and confiscation are entailed by breaches of the Act. Petroleum flashing above 120° F. may be exempted by the Governor from the operation of the Act. Powers of search of suspected premises are granted under warrant.

CHANNEL ISLANDS—*see* GUERNSEY AND JERSEY.

CHINA.

There are no general regulations relating to the transport of petroleum in China. At the open ports, the Customs regulations provide for the berthing of vessels carrying petroleum in a certain portion of the harbour. At Shanghai, the Municipal Council for the Foreign Settlements forbids the storage of petroleum within the limits of the Settlements, but allows each vendor to have not more than ten cases at any one time on his premises. At the other open ports, the regulations are practically the same. In China, probably each city has its own regulations, but what they are, is unknown to Europeans.

CYPRUS.

Petroleum Acts of 1883 *and* 1892.

No test standard is prescribed. Not more than 30 okes (750 fluid ounces) of petroleum, contained in separate well-stoppered vessels of a capacity not exceeding 12 okes (300 fluid ounces) each, may be kept, either for private use or for sale, except under license from the Municipal Authorities.

DENMARK.

The Statute Laws affecting petroleum are those of 26*th November*, 1870, and 8*th September*, 1875; and under these, the subjoined regulations have been issued :—

Storage (4*th June*, 1891).—Inflammable liquids, such as petroleum, turpentine, camphine and similar fluids, ether, petroleum, naphtha, solutions of gum in turpentine, and all other "dangerous" liquids, as defined by the Law of 26*th November*, 1870, are divided into two classes :—

A. Liquids evolving inflammable vapour at or above 40° C.

B. Those from which such vapour is evolved at temperatures below 40° C.

Only merchants and manufacturers using petroleum for industrial purposes, may store quantities exceeding 20 *potter*[1] of class A or 4 *potter* of class B, but even such persons may not keep more than 800 *potter* of class A or 160 *potter* of class B. If both classes are stored together, 1 *potter* of class B is considered equivalent to 5 *potter* of class A. For quantities of not more than 200 *potter* of class A, or 40 of class B, the only restriction imposed is that the liquids must be contained in closed bottles or tins; but for larger quantities, up to 400 *potter* of class A, or the equivalent of class B, the vessels (barrels are allowed for class A) must be stored in cellars with bricked walls and fire-proof flooring, well ventilated and in communication with the open air. Wood-lined cellars are also permitted, provided a covering of cement is applied to the walls and ceiling, with a lining of galvanised sheet iron of a minimum thickness of No. 20 B.W.G., and doors of the same strength are fitted. The window sills must be 1 foot above the floor level, and the windows protected by 5-mm.-mesh galvanised iron screens. Quantities in excess of the foregoing, must be kept in similar cellars, directly accessible from the open air by means of an iron door. In all cases, a supply of sand must be kept at hand in case of fire, and all barrels must rest on iron supports while being emptied.

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[1] A *pot* is 1·7 imperial pint.

Testing (*8th September*, 1871).—The apparatus prescribed by this decree is that known as the "Danish cup," a description of which is given on p. 553. To apply the test, the water bath is filled up to the mark, and the flame of the lamp regulated to produce a rise in temperature from 20° to 30° C. in six or seven minutes. The water is stirred before observing the temperature, and when the last-named degree is reached, the oil cup is placed in the bath, the thermometer being at the same time transferred to the former vessel. The test-flame is applied at each degree rise in temperature. The apparatus may be obtained at the Public Test Office, Copenhagen. In addition to these regulations, there is a law of *3rd August*, 1886, defining the limits within which petroleum may be stored in the City of Copenhagen, and another of *17th January*, 1884, providing for the berthing and discharge of import vessels. Ships carrying more than 16 "tonder" are allowed to anchor in the inner roads, but not to pass into the inner harbour. A red flag must be displayed at the foretop, and notice of arrival given to the harbour authorities, who will decide whether it is necessary to put a watch on board. Vessels with less than 16 *tonder*[1] on board may enter the harbour, but must discharge at once. In 1887, the Danish Government brought in a Bill for fixing the standard flashing point at 23° C. (Abel), but the Bill was withdrawn.

DOMINICA.

Petroleum Act, 1874.

Standard test 100° F. (presumably open flash-test). No testing regulations. Limit of quantity to be stored for private use or sale, 17 gallons, except in places appointed by the Governor. No sale allowed except under license from Magistrates, who may authorise storage of more than 17 gallons. Appeal to Governor allowed against Magistrates' refusal to grant license. Governor may make regulations for storage warehouses. Magistrates may issue search warrants, and aggrieved persons may appeal to Supreme Court.

[1] A *tonde* is 28·9 imperial gallons.

FALKLAND ISLANDS.

Apparently no regulations.

FIJI.

Kerosene Act, No. 27, *of* 1877.

No more than 80 gallons may be kept in a house or store unless 50 yards distant from other property. Larger quantities must be kept in Government warehouse. No test is prescribed, the term "kerosene" including all grades of mineral oils.

FRANCE.

The earliest regulations in France were formulated in the *Decrees* of 18*th April* and 31*st December*, 1866, relating to dangerous or noxious occupations,[1] the manufacture and distillation of petroleum, shale, and tar oils and allied substances being placed in the 1st category of such trades, because of the smell and the danger of ignition. Storage depôts were classified in the 1st or 2nd category, according to the character (*i.e.*, whether the flashing point was below or above 35° C.) of the oil stored. A further classification was made on the basis of quantity, stores containing between 1,050 and 10,500 litres of standard test oil, or 150 and 1,050 litres of low-test oil, being considered as belonging to the 2nd class, and those containing over 10,500 litres of standard-test oil, or over 1,050 litres of low-test oil, as in the 1st class. A little latitude was allowed, by the letter of instructions to the prefects, in the case of a store-keeper receiving a fresh supply before his stock was quite exhausted. The mode of ascertaining the degree of inflammability was prescribed by these regulations (see section on Testing, p. 550). Storage depôts were to be on the ground floor or in a cellar, the floors of cemented stone, and the door sills of stone, 1 decimetre above the floor, the dividing walls in the case of cellars being of 30 cm. masonry. Stores on the ground floor were to be of one storey only, the roofs resting on iron supports, and all depôts properly ventilated and well lighted by daylight only. No wood was permitted in any part of the structure. The only receptacles or storage vessels allowed, were stoppered metal bottles, sound iron-bound casks of 150 litres maximum capacity, or carboys of glass or earthenware protected from breakage by osier baskets, or packing in straw, &c., and holding not more than 60 litres, and transport was permitted only in such vessels. It was further prescribed that the transfer of oil from one vessel to another should only take place in daylight, and should, as far as possible, be effected by means of pumps. A few fixed lights were allowed in stores, but at a distance from the more inflammable oils, as also from those being retailed, and only absolutely safe, closed, portable lights were permitted when additional lighting became necessary. Smoking, fire, and the storage of empty barrels or other combustible matter were prohibited, and sand was to be kept in readiness to extinguish an outbreak of fire. An interesting portion of these early regulations is that which takes the form of advice to the users of mineral oils for illumination. The recommendations were substantially as follows:—Lamps should have the container large enough to hold more oil than would be burned at one time of using. Containers should be strongly made of transparent glass to facilitate inspection of the contents, and the fittings should be securely attached by means of a cement impervious to the oil, care being also taken that there were no apertures in the fittings to form a communication with the tube carrying the wick. Heavy pedestals to minimise risk of overturning, as well as extinguishing and trimming appliances, were recommended. A caution was given against the carrying about of lighted lamps, and suggestions were made in reference to replenishing. In case of the chimney breaking, the lamp was directed to be extinguished, to prevent overheating of the metallic fittings and the consequent danger of explosion, and the superiority of sand, earth, or ashes to water, in case of fire, was pointed out.

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[1] These occupations were divided into three classes, viz.:—

I. Trades which might, by reason of their unpleasant nature and danger, only be carried on at a distance from inhabited houses.

II. Occupations for which isolation was unnecessary if proper precautions were taken for public safety.

III. Pursuits not liable to become obnoxious, but which must be under police surveillance.

The present laws in France are epitomised in the following:—

Abstract of the Decree of the French Government relating to the manufacture and storage of, and wholesale and retail trade in, petroleum, 19th May, 1873.

By this decree, petroleum and its products, shale and tar oils, spirits and other liquid hydrocarbons for lighting, heating, the manufacture of colours and varnish, cleansing and other purposes, are divided into two classes, those giving off inflammable vapour below 35° C. being included in Class I., and all others being grouped under Class II., the mode of testing to be determined by the Minister of Agriculture and Commerce, with advice from the Consulting Committee on Art and Manufactures. Factories for manufacturing, distilling, and using any of the above substances on a large scale, are placed in the 1st class of dangerous, insalubrious, and objectionable establishments, as set forth in the Decree of 15th October, 1810, and the Ordinance of 14th January, 1815. Stores and entrepôts, where the articles in question undergo a simple washing with cold water, or transference from one vessel to another, are classified as follows in accordance with the system prescribed by the foregoing decrees:—

1st Class when containing over 3,000 litres of liquids of the 1st category (or the equivalent in the 2nd category).

2nd Class containing 1,500 to 3,000 litres of the same.

3rd Class containing between 300 and 500 litres.

Five litres of liquids of the 2nd category are taken as the equivalent of 1 litre of the 1st for the above classification, and other inflammable liquids, such as alcohol, ether, carbon bisulphide, &c., are divided into the 1st or 2nd category on exactly the same basis as the petroleum products. The places of storage must be surrounded by a wall at least 2½ metres high, with only one opening which must lead into a public road, and be closed by a strong iron-plated door kept locked from nightfall till morning, the key to be kept by the proprietor or his deputy. All workmen entering or leaving the premises by day must be under strict surveillance. The only dwelling for occupation at night, allowed within the walls, is the watchman's house, and this must be isolated by a wall at least 1·2 metre high, without opening. No buildings of any kind may be erected within 50 metres from the external walls of the store in the case of stores of the 1st class, and 4 metres in the case of stores of the 2nd class. The stationary plant or storage tanks must be at least 50 centimetres from the wall, and must admit of ready inspection. The flooring of the stores must be flagged or cemented and provided with gutters running into covered cisterns large enough to hold the entire liquids stored—in case of accidental leakage or spilling—and all must be kept in a serviceable condition. If the store is of sufficient capacity, and is either partly underground or surrounded by an efficient wall without any opening, the cisterns may be dispensed with. Any warehouse or shed used for storage must be of one storey only, incombustible, and well ventilated in the roof. Storage tanks must be of metal with movable covers, or iron-bound wooden vessels, and fixed, oil-tight, pumps must be used for transferring liquids of the 1st class to vessels at higher levels. No empty casks or litter of any kind may remain in the store. All operations, such as receiving, storing, weighing, and delivering, must take place only by daylight, access to the store at night being strictly prohibited, as well as smoking or the introduction of any fire, light, or matches. (*N.B.*—In the South of France, Italy, and Spain, portable charcoal fires are much used.) This prohibition must be conspicuously exhibited near the doorway. For extinguishing any outbreak of fire, a sufficient quantity of sand or earth must be kept close by the store. The Magistrates, subject to the approval of the Minister of Agriculture and Commerce, may impose any further special restrictions in the interest of public safety, and may also, subject to the same conditions, grant licenses on other terms offering the same degree of security. Stores of the 2nd and 3rd class, and those for liquids of Class II., are subject to the same regulations, but small stores for less than 300 litres of liquids of Class I., or the equivalent in liquids of Class II. (viz., 1,500 litres) require no license. The proprietor must, however, lodge with the Mayor of the Commune and the Prefect of the Arrondissement, a minute description of the surrounding locality. These stores are subject to the same regulations as others, for ensuring safety, and must be partly underground and surrounded by a bank of earth or masonry to prevent outflow. The regulations applicable to the retail trade are briefly as follows:—The retailer must give the Mayor and Sub-Prefect an exact description of the place, quantity, mode of storing, and delivery, and must store liquids of Class I. in proper metal vessels having not more than two apertures, effectually closed by tap or stopper, transference into other storage receptacles not being permitted. These vessels must not hold more than 60 litres each, and are to be plainly and indelibly marked "Inflammable Spirit;" they are to be kept isolated from the rest of the goods in the shop, and provided with a vessel attached to the tap to collect any droppings. Storage in cellars is forbidden, and for the prompt extinction of fire, a sufficient quantity of sand or earth must be kept on the spot. Delivery to customers may be made only in properly stoppered and labelled tins, filled direct from the storage vessels, and all such transfers may be made during daylight only. If the oil is kept stored in cans ready for delivery, and holding not more than 5 litres each, contained in a metal lined box forming a tank, delivery by artificial light is permitted. Liquids of Class II. are to be stored in metal tanks holding not more than 350 litres, plainly marked "Mineral Oil." Retailers are not allowed to keep a greater stock than 300 litres of liquids of Class I. or their equivalent. The retailer may store the liquids in original packages in warehouses or stores, in a yard or other detached space, provided the buildings are isolated from any building containing combustibles, are well ventilated, kept locked, and are surrounded by a solid earth, brick, or stone wall forming a cistern to prevent outflow. Additions may be made to the foregoing regulations, in the interest of public safety, by the Prefect, under advice from the Sanitary Council. Traders already licensed under the old law may continue, but may not make any alterations except in conformity with these rules, and any contravention of the same on the part of any trader or storer will be visited by fines and closing of the premises. Transport of all inflammable liquids must take place exclusively in suitable metal tanks or wooden barrels. This decree revokes that of *27th January*, 1872, and amends that of *31st December*, 1866, in so far as relates to the storage of hydrocarbon liquids. Prefects of Police are vested with the powers conferred by this decree on Prefects, Sub-Prefects, and Mayors, and the execution of the decree is vested in the hands of the Minister of Agriculture and Commerce.

The question having arisen as to how far the regulations in the decree of the *19th May*, 1873, are applicable to the retail trade, in respect to inflammable liquids of the second class, the Minister of Commerce addressed a Circular Letter, dated *22nd November*, 1893, to the Prefects of Departments, stating that the Consultative Committee on Arts and Manufactures, having deliberated on the subject, had come to the conclusion that, while the restrictions as to carrying on all operations in daylight only, the stores being closed at night, applied to large stores, irrespective of the class of liquid contained in them, it was not intended that they should apply to retail establishments, except as regards liquids of the first class—*i.e.*, flashing below 35° C.,—and that consequently, retailers of high-test oil (Class II.) are not debarred from selling by artificial light.

Testing.—The first testing directions were prescribed by the decree of *31st December*, 1866, the weight of a litre of the oil being fixed at 800 grammes minimum, and the standard igniting point at 35° C. The test was applied by heating the oil in a copper cup, 6 to 7 cm. in diameter by 2 to 3 cm. in depth, placed in a water bath. When the temperature reached 35° C., as indicated by a thermometer placed in the oil, a lighted match was to be drawn across the surface of the oil and then plunged into the liquid. If the match was extinguished without igniting the oil, the latter was considered to have passed the test. In order to remove the objection that at the moment when the thermometer indicated 35°, the oil itself would be at a somewhat higher temperature, it was provided that, in case the owner of the oil raised this objection, the test should be repeated by heating the oil up to 36° or 37° C., allowing it to cool, and applying the match at the instant the thermometer marked 35°.

The testing instrument now employed, is the Granier, a description of which is given on p. 580. The standard of test remains the same, viz., 35° C., although the apparatus records the flashing point of the oil, whilst with the tester previously in use, the ignition point was taken.

GAMBIA.

Apparently no regulations.

GERMANY.

BERLIN.

Law of 4th August, 1883.

The law relates to crude petroleum and its distilled products (including petroleum ether, gasoline, benzine, ligroïn, neolin, naphtha, essence of petroleum, refined petroleum, oil for cleaning purposes, lubricating oils), and oils made from lignite or coal tar (viz., photogene, solar oil, benzol, &c.), and shale oil. These liquids are divided into two classes as follows:—

Class I. Those which flash below 21° C. (= 69·8° Fahr.), Abel-Pensky test, at 760 mm. barometric pressure, as prescribed in Imperial degree, 24th February, 1882, § 2 (R. G. Bl. § 40).

„ II. Those which flash above this point.

When kept on premises occupied or used by people, particularly in dwellings, including the kitchens, the adjoining store rooms, in offices, hotels, public-houses, and workshops, the maximum quantity allowed is—

Class I. 2 kilos.

„ II. 20 kilos., which must be kept as directed for shops.

A retailer may keep, of:—

Class I. 15 kilos., if it is all kept in metal vessels; or of
„ II. 300 kilos., if it is all kept in metal vessels, or 50 kilos. if not all so kept.

When more than half a litre of mineral spirit is sold, it must be in zinc vessels. Below this quantity, it may be sold in well-closed glass bottles. It must not be transferred from one vessel to another by artificial light.

When the quantities exceed those above allowed for retail shops viz.:—

Class I. 15 kilos., and do not exceed 100 kilos.;
„ II. 300 kilos., and do not exceed 1,000 kilos.,

the premises must be registered with the local police. These larger quantities may only be stored, in cellars or otherwise, on a ground floor, without any drains or outlets communicating with the street, and not artificially lighted or heated, but provided with good ventilation. The floor of this part of the premises must be of impermeable and incombustible material, inclosed by a continous and fireproof wall of such a height that the space within this surrounding wall shall be large enough to contain all the liquid therein if suddenly liberated. Or such storage may take place in courts, gardens, or other pieces of land properly fenced in, if the escape of the liquid is prevented by burying the casks, or by a fireproof enclosure. The drawing off of the liquid in these places and the handling of the same is allowed by daylight only. No license is required, but registration is necessary.

When the quantities exceed those allowed above, viz.:—

Class I. 100 kilos., and do not exceed 1,000 kilos.;
„ II. 1,000 kilos., and do not exceed 10,000 kilos.,

then a license must be obtained from the local police, who in granting it are to have regard, so far as circumstances may appear to render necessary, to the conditions laid down for the storage of unlimited quantities; and in no case may they dispense with the conditions laid down above. When the quantities are still larger, viz.:—

Class I. Exceeding 1,000 kilos.,
„ II. Exceeding 10,000 kilos.,

then a license must be obtained from the imperial police (as distinguished from the local police). The following regulations (subject to such occasional deviation as special circumstances may appear to render necessary and advisable) are to be observed in such places of storage. (*a*) The warehouses or wharves must be surrounded by a wall at least 2·5 metres high, and accessible all round in case of fire. (*b*) There must intervene between the liquids (or all buildings containing the liquids) and any building outside the wall, a distance of not less than 60 metres. (*c*) The flooring or ground of those parts of the premises where liquid is to be stored, must be constructed of impermeable and incombustible material, and have an incline of at least 1 in 100 towards one or more reservoirs fitted with grating; and the floor must be sunk below the level of surrounding ground or be surrounded by a continuous fireproof enclosure. In either case, the tank capacity (inclusive of the reservoirs) must be sufficiently large to contain the whole quantity of liquid stored therein should it all become suddenly liberated. (*d*) If the liquid is stored in buildings, they must be surrounded by massive stone walls and be of one storey only, well lighted and ventilated, and not artificially lighted inside or out. (*e*) Business must be carried on upon the premises by daylight only, and only a watchman may be allowed at night. (*f*) No light, fire, smoking, matches, &c., is allowed on the premises. (*g*) No dwelling place is permitted on the premises except one for the watchman, which is to be separated from other parts of the premises by a wall. The regulations (*a*) and (*b*) (surrounding walls and observance of particular distances) may be dispensed with where only liquids of Class II. are kept, but the licensing authorities are, in such cases, to assign conditions as to the enclosure and the distances to be observed. It is directed that—

1. Where liquids of Class I. are kept with those of Class II. (or other inflammable liquids), or are separated therefrom by partitions not constructed throughout of fireproof materials and free from openings, the regulations applicable to Class I. will apply to the whole.

2. Where liquids of Class II. are kept with other inflammable liquids, or separated therefrom by partitions not constructed throughout of fireproof materials, or free from openings, the regulations applicable to Class II. will apply to the whole. The rules do not apply to places where crude petroleum is produced, or factories where the products are made or used for manufacturing purposes, these places being subject to the Industrial Ordinance (or Factory Act), and regulated by the competent authorities thereunder. Licenses are not required for existing places for unlimited storage, or for warehouses already existing, where the regulations are complied with in respect to the quantities kept.

Transport in Berlin.—Conveyance of liquids of Class I. in carboys by van is allowed, provided the carboys are packed securely in wooden boxes (or, if singly, in tubs or baskets), well lined with straw or other protective material, properly fastened down.

BREMEN.

Law of 3rd May, 1872.

The law relates to all oils which give off inflammable vapour or ignite easily (except vegetable and animal oils), and all kinds of liquids possessing the same properties. The classification is as follows:—

(*a*) Oils and liquids giving off inflammable vapour at a temperature below 30° Réaumur (100° F.).

(*b*) Oils and liquids giving off inflammable vapour at 30° Réaumur or above.

The quantities and authorised modes of keeping are—

Retail Shops.	**Stores.**[1]
Class (*a*) 100 lbs.,	1,500 lbs.
Class (*b*) 300 lbs.,	3,000 lbs.

In shops (other than chemists' shops) the liquids must be kept and delivered in well-closed, completely filled vessels of metal, glass, china, or earthenware, and containing no more than 50 lbs. The opening of such vessels, and transference of the contents into other vessels in shops, is prohibited. The liquids, if not used for burning, must be kept in well-closed vessels of metal, glass, china, or earthenware. In excess of the foregoing quantities, the liquids must be kept in public warehouses approved by the police authorities. Use of fire or matches and smoking, are prohibited in warehouses and stores, as well as on board ships laden with inflammable liquids. Naked lights are generally prohibited, but in a shop, fixed gas jets or well protected lamps or lanterns are allowed, though no exposure of inflammable liquids may take place by artificial light.

Loading, Landing, and Storage of Petroleum and Solar Oil.

Senate Law, 26th Nov., 1866.

This decree provides, that in view of the inflammable nature of these oils, all quantities exceeding 1,000 lbs. (German) must be kept in a specially appointed store under police supervision. Masters of vessels arriving are to give notice to the harbour authorities, stating what quantities of crude or refined oils are on board, and to moor their vessels according to directions. No loading, discharging, or removal of petroleum vessels is allowed without special permit. Fires, lights, and smoking are prohibited on petroleum vessels.

Testing Regulations of the Bremen Petroleum Exchange, relating to Colour and Flashing Point.

The proprietor of a parcel of petroleum wishing to have its colour and (or) flashing point tested, must send his barrels marked for identification, to the quay or the wharf, and forward to the test office a signed declaration with the fees as determined by the Exchange.

The barrels will be sampled and the samples mixed by the testing officials as follows:—

Up to 100 brls.	6 brls.	to be sampled,	equal to	2 test samples.
From 101 to 200 ,,	9 ,,	,,	,,	3 ,,
,, 201 to 300 ,,	12 ,,	,,	,,	4 ,,
,, 301 to 500 ,,	15 ,,	,,	,,	5 ,,
,, 501 to 700 ,,	18 ,,	,,	,,	6 ,,
,, 701 to 1,000,,	21 ,,	,,	,,	7 ,,

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[1] The stores must be well ventilated, situated in cellars or basements, entirely separated from other parts of the premises used for trading, industrial or domestic purposes, and kept locked. There must be no drains communicating with premises on a lower level; sewers, &c., are allowed.

Over 1,000 barrels, 2 per cent. are sampled, or as many over 2 per cent. as shall be necessary to make the number of samples a multiple of 3. Closing the barrels after sampling is to be done by the owner or at his expense. For testing the flashing point, the Abel apparatus (approved by the Imperial Commission of Standards and in accordance with the Imperial Chancellor's Schedule, 20th April, 1882) is used.

If all the samples pass the standard test of 21°C. flashing point, at 760 mm. pressure, the parcel they represent is declared tenderable on spot and forward-delivery contracts, and each barrel is marked as complying with the test of the Bremen Petroleum Exchange ("Reichstest der Bremen Petroleum Börse").

N.B.—Corrections are made for barometric pressure according to a table published by the Chancellor (see p. 570). If any of the samples flash below 21° C. at 760 mm., then the parcel is condemned as not tenderable on contracts. In such case, the owner can have it re-tested in parts of not more than 100 barrels each, making a fresh declaration for each parcel. Oil flashing below 21° C. must be branded on the barrels as "highly inflammable," or, at the request of the owner, may be marked with the interim stamp of the Exchange, provided he furnishes an acceptable guarantee that such oil shall not be entered into the German Empire for sale. For testing the colour of the oil, Wilson's chromometer is the standard instrument used. The following is the classification :—(1) Prime white, (2) standard white, (3) prime light straw to white, to standard white, (4) prime light straw to white, (5) light straw, and (6) straw. The colour is indicated on the barrels, by one of the preceding numbers added to the test stamp. If the owner is not satisfied with the result of the colour test, he can have the test repeated on any part of the parcel. For oil, not below standard white in colour, which passes the test of flashing point, a certificate to that effect is given; for all other oils, the certificate is given according to quality. Such certificates are to be signed by the Director of the test office or the second official.

PORT OF BREMERHAVEN.

Regulations of the Harbour Board for the Discharging, Loading, and Storing of Petroleum and Solar Oil (mineral oil distilled from lignite).

15th April, 1877.

Vessels carrying these oils will, as a rule, and provided that their admission is consonant with the harbour regulations, be allowed to enter the Kaiserhafen only. The captain must report to the Harbour Authorities the nature of his cargo, and the number of barrels which it comprises, before entering the dock, the maximum penalty for omission being 20 marks per barrel. Watchmen are appointed, at the ship's expense, to ensure the absence of all lights, fire, and matches, and to prevent smoking. Cargo must be discharged immediately the ship is at the berth, care being taken to avoid blocking up gangways on board or on shore. Storage is effected in the manner prescribed by the regulations of 18th September, 1874. Vessels loading must leave immediately the cargo is all on board. Vessels discharging must be thoroughly cleansed, dunnage wood stored or disposed of by direction of the Harbour Authorities, and all rubbish taken ashore at once. The Harbour Authorities are empowered, under certain circumstances, to refuse admittance to the harbour, or to expel from the harbour, ships already admitted, and to impose fines for breaches of these regulations.

For tank steamers importing petroleum in bulk, the following regulations are in force:—Tank steamers about to discharge their cargo in the Kaiserhafen with their own steam must get up steam in the roads. In putting out the boiler fire, it must not be raked out on to the floor plate, but allowed to burn out in the fire-box. Sampling the oil and driving out the vapour from the tanks must be carried out in presence of the official watchman, and in the roads. While the vessel is in the Kaiserhafen, no tank hatches may be unscrewed except of those tanks actually being pumped out, and these covers must only be raised sufficiently to admit air for the prevention of rarefaction in the tank. Hatchways may only be completely opened during daylight, and when the tanks are empty, and the covers must be replaced without loss of time. The boiler arrangements must conform to the Imperial Regulations, and be open to examination by the inspector of boilers. The pump boiler chimneys must be provided with spark catchers. Due notification to the authorities of the arrival of a tank steamer, is compulsory, and the consignee is responsible for the conveyance of the necessary watchman on board while the vessel is still lying in the roads.

HAMBURG.

Law of 20th December, 1882.

Law applies to—A. "Crude petroleum and its lighter products" (including refined petroleum having a flashing point below 21° C. (69·8° F., Abel-Pensky test). B. Refined petroleum and turpentine.

Class A. may be stored up to 50 kilos. without any license, but subject to the following regulations:—The liquid must be kept in tin vessels bearing prominently on a red ground the words "highly inflammable," and must be handed to the purchaser in vessels similarly labelled. The sale must take place by daylight, and the store must not be entered with a naked light. When the liquid is low-test refined petroleum, a metal vessel for keeping is not compulsory. Low-test refined petroleum may only be stored within the limits of the petroleum harbour, except by special permission, under which dealers may store on their premises up to 150 kilos. provided the vessels are marked "highly inflammable," and, in addition, "special precautions to be taken if used for burning," if sold in vessels containing less than 50 kilos.

Class B.—On private premises outside the petroleum harbour, refined high-test oil may be stored up to 50 barrels without special license, subject to the following regulations:—(*a*) The storage place must be surrounded by massive walls. (*b*) The storage place must have no communication with sewers, canals, streets, or courts. (*c*) The flooring must be at least 0·6 metre below the level of the street or court, and must always be covered with a layer of sand 0·3 metre thick. (*d*) The storage place must be detached. (*e*) Smoking is strictly prohibited. (*f*) Only "ball lanterns" may be used if artificial light is required. Turpentine may be stored up to 800 kilos. without special license, and subject to the above regulations (*a*) to (*f*). There are regulations as to landing, shipment, &c.

Special licenses are required for quantities exceeding:—of class A, 50 kilos., of class B, 50 barrels; and of turpentine, 800 kilos. But when the quantity of oil or turpentine exceeds one barrel, it must be kept in a detached and specially constructed store with provision against escape.

Harbour Regulations.

Vessels carrying crude petroleum and its lighter products, refined petroleum, or turpentine, must report on arrival, to the officer of the guardship at the Ionas, and a declaration must be made by the captain, of the quantities he has on board. Ships having crude oil or the lighter products on board must anchor at a safe place in the lower part of the Elbe near Twielenfleth, and may only discharge with the sanction of the Harbour Police Authorities, and under conditions imposed by them. Vessels laden with refined petroleum or turpentine may discharge in the petroleum harbour only. No lights or fires are allowed on board, no smoking is permitted, and the hatches must be kept open to prevent the accumulation of explosive vapour.

GIBRALTAR.

Ordinance, 23rd Feby., 1884.

Importation of petroleum flashing below 73° F. (Abel), is prohibited, except such as is required for military purposes. With the same exception, the limit of quantity which may be landed and stored for private use, or otherwise, is 24 gallons, unless under license from the police magistrate (who may impose suitable conditions). All licenses are registered by the Justices' Clerk. The captain of the port is authorised to regulate the mooring of vessels carrying petroleum, subject to the approval of the Governor. Breach of this ordinance is punishable by penalty and confiscation of the oil. The Justices may authorise search of suspected premises, and obstruction of search party involves fine and confiscation of oil found.

GOLD COAST.

The storage and sale of petroleum in this colony are not subject to any regulations.

GREECE.

The sale of petroleum was established as a Government monopoly by decree of 1st February, 1884.

GRENADA.

Inflammable Goods Ordinance, 1891.

The standard test is 80° F. (Abel), all low-test oil being classed as "volatile petroleum." Importation of volatile petroleum is prohibited under penalty of forfeiture and imprisonment. Consignees must give notice to the Treasurer within six hours (Sundays and holidays excepted) of the vessel's arrival, and must send at least three samples to the Government Inspector to test. The landing and storage of standard-test oil are allowed at places appointed by regulations. The consignee of volatile petroleum may be allowed to re-export within thirty days on proof of ignorance of the low-test quality of the oil. Appeal against Inspector's test is decided by competent persons; fees to follow result. In the port of St. George, no oil is to be landed except between 7 a.m. and 4 p.m., unless by special permission. Not more than 2 cases is allowed on private premises, nor more than 12 cases on traders' business premises. Not less than 4 cases may be taken out of the Petroleum Warehouse at a time, unless in the case of the balance of an importer's stock. Revenue and police officers have the right to search suspected premises.

GUERNSEY.

Law relating to Oils, Mineral or Vegetable Essences, or other Substances of a similar nature, registered 22nd July, 1893.

This law applies only to substances "susceptible of producing, in a closed vessel, inflammable vapours at a temperature below 73° F." (testing instrument not specified). A quantity not exceeding half a gallon may be kept for private use in a dwelling-house; but it must be contained in well-corked metal or glass vessels. A license is required for the storage and sale of such substances, the limit of quantity allowed under license, being 5 gallons. Licenses are granted without charge for a period of one year, on application to the douzeniers or constables of the parish, giving full description of the store, provided that the store is found on examination to be suitable for the purpose. Appeal is allowed to the full Court in case of refusal of license by the constables or douzeniers. Constables and assistant-constables may at all times visit stores or selling places to see if the law is complied with, and may have all goods kept in contravention of the regulations, removed to a place of safety. Hawking such substances is prohibited, as is also selling or retailing after sunset. Masters or agents of import vessels carrying oils or other substances of low test, must declare the quality and degree of inflammability of such oils, &c., and give consignee's name. The goods must be landed and removed under direction of the harbour-master during daylight only, except by special permission, and must not be left on the quays or any part of the harbour, except at places appointed by the harbour-master. Infractions of the law and obstruction of inspectors are punishable by fine, with or without imprisonment and confiscation of goods.

HOLLAND.

The legislative restrictions in this country are local only.

AMSTERDAM STORAGE REGULATIONS.

The Police Regulations of 1*st December*, 1886, made provision for the storage of petroleum and similar oils and other liquids, and prescribed:—That except in the public store, no quantity exceeding 10 litres of petroleum, petroleum-ether, petroleum-naphtha, benzol, or other easily inflammable oil or liquid derived from petroleum or tarry substances, igniting at a temperature lower than 32° C., when tested by the instrument prescribed by the Burgomaster and Council, should be stored in any building, unless in metallic vessels containing not more than 2 litres each. The limit of quantity for oils passing the test was fixed at 400 litres, with the following exceptions, in which cases the limit was raised to 6,000 litres:—

(1) When kept in closed metallic vessels or casks.

(2) In the public store.

(3) In properly constructed cellars, or buildings level with the street, the floor and walls being covered with water-tight iron plates, and the outer door provided with a stone sill of sufficient height to prevent outflow. Operations in these stores were allowed to be carried on during daylight only, all lights, fires, glowing substances, and smoking being prohibited. The oils stored were to be kept in closed metallic vessels or casks, of 200 litres maximum capacity, and no low-test oils, empty barrels, or any easily inflammable goods might be kept on the premises. The provision of a quantity of sand to extinguish an outbreak of fire was enjoined and the nature of the goods stored was to be indicated by a painted signboard outside.

Railway companies and forwarding agents were only allowed to keep such oils, while on their premises, in such places and subject to such conditions as the burgomaster might prescribe, and not more than 6,000 litres of standard-test oil, or 200 litres of low-test oil might be forwarded by land carriage, except by permission. Special authority was also necessary for storing oils or oil barrels from sunset to sunrise on quays or in the open street, or for the storage in any yard or building, of more than 100 empty oil casks. Masters of vessels carrying the aforesaid oils were required to give notice to the Police on arrival in harbour, and to obey the orders of the harbour- or dock-master during their stay, which was limited to forty-eight hours in the case of river vessels carrying more than 1,000 litres of low-test oil, or 6,000 litres of standard test oil, and to eight days in the case of sea-going vessels carrying more than 1,000 litres of low-test oil. In the loading or landing of more than 200 litres, or 6,000 litres, of the above-mentioned oils respectively, masters of vessels were required to take such precautions for public safety, as the authorities might consider necessary.

These regulations, so far as regards shipping, land carriage, and storage, are confirmed by the existing ordinance of 2nd September, 1890.[1] The standard of test is, however, changed to 21° C. (Abel, or other instrument decided on by the Burgomaster, and the following substances are classed with low-test oil—viz., liquids, such as naphtha, carbon bisulphide, benzol, and ether and all preparations in which these occur, which ignite in contact with a naked light, but are not miscible with water in all proportions. Liquids such as alcohol, wood spirit, &c., which, although inflammable by contact with a light, will mix with water in any proportion, are classed with standard-test oils. The occupiers of stores are required to furnish samples for testing, of the substances stored, on demand by the Burgomaster, who must keep a register of the names and addresses of persons storing inflammable goods and of the quantities kept. Amongst the other dangerous substances affected by the regulations of 21st September, 1880, are gunpowder, phosphorus matches, fresh roasted coffee, charcoal, bone-black, rosin, used engine waste or cotton rags, all of which must be kept in iron receptacles; unslaked lime, which must be stored in perfectly dry places; hay and straw; wood shavings or chips. Fuel and tar may not be stored in larger quantities than 5,000 kilos. except under special permission, which is also necessary if it is desired to keep empty barrels or other oil casks in stores.

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[1] With the addition that petroleum vessels must fly a P-flag at the foretop.

LEGHORN.

Port Ordinance, 23rd June, 1873.

No petroleum, turpentine, or benzine, naphtha, is allowed to remain on the quay longer than twenty-four hours, except by permission of the burgomaster and magistrates, and under police supervision at the expense of the parties concerned. No inflammable goods may be unloaded or loaded unless in the presence of a harbour official, except by permission of the harbour-master. Loading must take place during daylight; no artificial lighting being allowed. Before removing any such goods, the buyers or forwarding agents must, in writing, inform the harbour-master of the description, marks, numbers, quantity, and destination of the same, and the removal must be superintended by a harbour official. The sale of crude petroleum within the city is forbidden, and no naphtha may be sold in greater quantity than 25 litres. Unloading, loading, and forwarding such articles are only allowed under police supervision. Not more than 30 barrels of 250 kilos. of refined petroleum or turpentine may be kept in a store, and that only by permission of the burgomaster. Railway companies and forwarding agents may store petroleum intended solely for transport outside the city in their premises, provided complete isolation is secured. Not more than 250 litres of refined petroleum or turpentine, or 25 litres of benzine, may be kept in a shop, and notice of intention to store must be given by the shopkeeper to the authorities. The masters of vessels loading more than 150 barrels of petroleum must advise the authorities, who will appoint a loading place. Stranded iron lighters, holding up to 300 barrels, may be used as stores under supervision of the harbour-master.

By *Municipal Ordinance No.* [illegible] *of* [illegible] *July*, 1885, the storage of petroleum, naphtha, petroleum-ether, benzin, benzine, oil of turpentine, and other tar and petroleum products inflammable below 32° C., according to the test prescribed by the burgomaster and council, is only allowed to the extent of 25 litres, and in closed metal cans containing not more than 2 litres each. The limit of quantity to be stored in one building, without license, for the remaining descriptions of these articles (*i.e.*, oils, &c., passing the standard test) is 200 litres, which must be kept in stoppered metal, stone, or glass vessels, or closed casks. Shopkeepers must give notice to the burgomaster and council of their intention to store. The storage of any of the above-named substances in the open street between sunset and sunrise is prohibited, except under police supervision and with the consent of the burgomaster, which is also requisite before storage can be effected in any open space. The landing, loading, or storing of naphtha and other inflammable substances at the quays, is only allowed under police supervision at owners' cost, and on previous notice being given to the police of the quantity, description, marks, and numbers, &c., of the goods. In 1875, the Municipality, by the ordinance of 2nd June, prohibited the storing of more than 25 litres of benzine, or 300 barrels of refined petroleum or turpentine, elsewhere than at the petroleum store at Charlois. The limit of quantity to be stored in shops, under license in town, is now 25 barrels.

The Directors of the storage warehouse at Charlois have established a testing department in which the flashing point of petroleum samples is ascertained in accordance with the German method, the Abel-Pensky instrument being employed. The oil is sampled in the same manner as in Bremen. A certificate of the result of the tests is furnished, and if the oil passes the standard test of 21° C. at 760 mm., barometric pressure, each barrel is stamped :—

PAKHUISMEESTEREN. ROTTERDAM. DEUTSCHER REICHSTEST.

HONG KONG.

The Dangerous Goods Ordinances of 1873 (*No.* 8) *and* 1884 (*No.* 7) empower the Governor to prescribe conditions of storage under license, kerosene for private use up to 10 gallons, kept in closed vessels containing not more than 3 gallons each, being exempted. License to store in shops up to 40 gallons is granted, provided that the petroleum is kept in the original tins and stored in a brick-lined well, fitted with an iron-lined wooden lid for protection in case of fire (4th May, 1880). For stores, the premises must be either of brick or stone, with concrete floor, plastered up to the door sill (3 feet from floor) with Portland cement. Ventilation must be effected by windows on both sides, protected by wire-netting and sun-blinds. Roof must be of four thicknesses of tiles, or double-tiled with plaster ceiling. A 10-feet wall must surround the building at a minimum distance of 10 feet, and the sill of the door or gate in the said wall must be 3 feet from the ground inside. No kerosene may be stored above the window sills. No leaky tins, matches, lights, or unlicensed combustible articles may be kept on the premises. The stôre must remain closed between 6 p.m. and 6 a.m. from October to March, and between 7 p.m. and 5 a.m. from April to September.

Licensees must notify every month, to the Superintendent of the Fire Brigade, the quantity of kerosene in stock. Ventilators must be provided with iron shutters, and metal shades. Soldering is allowed only in a specially-constructed sunken space surrounded by a wall 2 feet high and having a cemented floor, with drain leading to a small well, to collect waste oil. Damaged cans may be kept only in an open shed with tiled roof.

INDIA.

Acts No. XII. of 1886, *No. XIV. of* 1890, *and No. XII. of* 1891.

The earliest regulations governing the storage and transport of petroleum in British India, were contained in the *Act of* 1865 "*for the prevention of injury from fire in ports, and to provide for the safe keeping of inflammable oils in ports and places in the Provinces of Bengal,*" the term "inflammable oil" being applied to all oils, or their products, giving off inflammable vapour below 100° F., the method of testing not being stated, but the open flash test being evidently referred to. Not more than 40 gallons was allowed to be kept within 50 yards of a dwelling or warehouse, nor more than 20 gallons to be transported from one place to another except under license, any infringements of these rules involving confiscation and fines. In the *Indian Ports Act,* 1875, *sec.* 32, the Local Government was empowered to make regulations for the mooring, loading, or unloading of vessels containing inflammable oils. Both these Acts were repealed by *No. VIII.* of 1881, which fixed the standard of test at 73° F. (Abel), all more volatile petroleum being termed "dangerous." Lubricating oil, flashing at or above 250° F., was exempted. The limit of quantity of "dangerous" oil to be stored or transported without license, was fixed at 3 gallons, and this had to be kept in separate stoppered bottles holding not more than one pint, and conspicuously labelled. Of other petroleum, a maximum quantity of 500 gallons was allowed to be stored without license.

The Act of 1881 was repealed by Act XII. of 1886, which defined "petroleum" and "dangerous petroleum" in the following terms:—

(1) "Petroleum" includes also the liquids commonly known by the names of rock oil, Rangoon oil, Burma oil, kerosine, paraffine oil, mineral oil, petroline, gasoline, benzol, benzoline, benzine, and any inflammable liquid which is made from petroleum, coal, schist, shale, peat, or any other bituminous substance, or from any products of petroleum; but it does not include any oil ordinarily used for lubricating purposes and having its flashing point at or above two hundred degrees of Fahrenheit's thermometer.

(2) "Dangerous petroleum" means petroleum having its flashing point below seventy-six degrees of Fahrenheit's thermometer: Provided that, when all or any of the petroleum on board a ship, or in the possession of a dealer, is declared by the master of the ship or the consignee of the cargo, or by the dealer, as the case may be, to be of one uniform quality, the petroleum shall not be deemed to be dangerous if the samples selected from the petroleum have their flashing points, on an average, at or above seventy-three degrees of Fahrenheit's thermometer, and if no one of those samples has its flashing point below seventy degrees of that thermometer.

The Act of 1886 was amended by Acts XIV. of 1890 and XII. of

1891, the following clauses being substituted by the Act of 1890 for the original clauses in the schedule prescribing the mode of testing :—

> If the flash takes place at any temperature below 77° Fahrenheit, the temperature at which it occurs is to be recorded. Two fresh portions of the sample are then to be successively tested in a similar manner and the results recorded. If no greater difference than 2° Fahrenheit exists between any two of the three recorded results, and if in no instance the flash has taken place within eight degrees of the temperature at which the testing is commenced, each result is to be corrected for atmospheric pressure as hereafter described, and the average of the three corrected results is the flashing point of the sample. In the event of there being a greater difference than 2° Fahrenheit between any two of the results, while in no instance has the flash taken place within eight degrees of the temperature at which the testing was commenced, the series of tests is to be rejected, and a fresh series of three similarly obtained, and so on, until a sufficiently concordant series is furnished, when the results are to be corrected and the average taken in the manner already described.
>
> If, however, a flash has occurred at or below 64° when the tests are applied in the manner described, the next testing shall be commenced ten degrees lower than the temperature at which the flash had been previously obtained (that is to say, at 54° or thereunder), and this procedure shall be continued until the results of three consecutive tests do not show a greater difference than 2°, and until a flash has not occurred in any of the three tests within eight degrees of the temperature at which the testing is commenced: Provided always that, if at the commencement of the series of tests a flash has occurred on the first application of the test-flame at 56°, and if a flash has also occurred on the first application of the flame in each of three successive tests in which, thereupon, the test-flame is first applied at 46° as above directed, the testing officer shall certify that the petroleum has a flashing point below 47°, and the sample shall be reported dangerous.

The limits of quantity of "dangerous" and other petroleum, which may be stored and transported without license, are those fixed by the 1881 Act, and "dangerous" petroleum kept in the small quantities allowed, must be labelled "highly inflammable," together with the name and address of the consignee, sender, or vendor. The Local Government is empowered to specify the places of import, to make regulations in connection therewith, appoint testing officers, fix the number of samples to be drawn from a cargo declared to be of uniform quality, decide upon the division of cargoes in case of doubt as to their uniformity, and fix the fees for storage and testing. The Local Goverment is likewise empowered, under sanction of the Governor in Council, to specify where petroleum produced within its territories may be refined, to arrange for the testing of the same, and to prevent the removal of "dangerous" petroleum so produced, except in conformity with the Act. The Local Government may also make rules for the granting of licenses for storage and transport, and for the testing, in transit or in store, of "non-dangerous" petroleum. The Local Government may call upon the consignee of any low-test oil, to have the same refined, to take out a license for it as "dangerous," or to re-export it, or may allow the oil to be re-tested. The Local Government may also, at discretion, exempt from the Act any oil flashing at or above 120° F. Inspectors have power to require dealers to show them their stock, and to sell them samples for testing; they may give notice in writing of their intention to test such samples, and may issue a certificate of the result, a copy of which shall be supplied free, on request, to the dealer.

Breaches of the provisions of the Act render offenders liable to fines, with confiscation of the oil. All testing apparatus must be verified at least once every five years, by the Government Chemical Examiner in Calcutta, who shall stamp the apparatus and issue a certificate as to its absolute or relative correctness, and the means of rectifying the variation, if any.

British Burma and British Baluchistan are under the same law as India.

Testing.—Regulated by the Acts of 1886 *and* 1890.

The Abel instrument with clockwork slide movement (Abel-Pensky) is now used. The test is applied in the manner described in Section IX. (p. 562).

ISLE OF MAN.

Dangerous Goods Acts, 1871 *and* 1881.

Storage Regulations, 12*th May*, 1882.

"Petroleum" under the first-named Act, included all products of naphtha and petroleum oils flashing below 100° F. (open test), but the Act of 1881 amended this definition so as to include all petroleum products. A license from the Governor is required for the storage of petroleum, with the following exceptions:—(1) In the case of oil flashing below 73° F. (Abel): a quantity not exceeding 1 gallon, kept in well-stoppered vessels holding not more than a pint each, whether for private use or sale. (2) In the case of other petroleum: a quantity not exceeding 40 gallons. Any oil kept in contravention of the Act may be confiscated, and a fine inflicted on the offender. All low-test oil kept beyond a period of seven days after landing, conveyed to any place on the island, or exposed for sale, must be plainly labelled with the words "highly inflammable," in addition to the description, and marked with the name and address of the consignee or owner, sender, or vendor. *Test.*—The standard is now 73° F. (Abel), and the mode of testing is the same as in the English Act of 1879. Storage licenses are granted under the following conditions:—The place used as a store may be either an open space or a shed of one floor only (with an exception in favour of a one-floor shed having a vault underneath, provided the other conditions are complied with), the floor of which must be sunk 2 feet below the surrounding surface, or have a wall 2 feet high surrounding it, made perfectly secure against outflow or leakage, and properly ventilated to prevent the accumulation of petroleum vapour; having, in addition, a well to receive the leakage from any of the storage vessels, such well not being in communication with any public drain or sewer. No other goods may be kept in a petroleum store, except such as are not combustible. No smoking, lights, fires, or matches are allowed in stores, or on ships or other conveyances during loading, unloading, or conveying petroleum in greater quantity than 36 gallons; and no delay, beyond what is absolutely necessary, is allowed in the carrying out of these operations, eighteen hours being allowed for the loading and discharge of vessels. Petroleum ships must conform to harbour regulations or orders of harbour-master with respect to moorings, &c. Inspectors are appointed by the Governor, and may search suspected premises, under warrant from the high bailiff or justice of the peace, being authorised to seize any petroleum kept in contravention of the Act. Officers of Customs, head constables, and inspectors and sergeants of police may exercise the same powers without warrant, and any person obstructing such entry or seizure, is punishable by fine. If objection is raised against the inspector's test, the Court may appoint a public analyst or other competent person to decide.

ITALY.

In Italy, the different Municipalities have power to frame their own regulations for the storage, &c., of petroleum, subject to the approval of the Provincial Deputation and the Home Office, under the *Law of Public Safety, No.* 9, 20*th March*, 1865 (*Arts.* 88 *and* 89). Carriage of mineral oils by rail is subject to the same conditions as that of explosives and other inflammable materials. The above-mentioned Law empowers the Provincial Deputations to proclaim and prohibit the establishment of noxious, dangerous, and objectionable manufactures.

GENOA.

Petroleum and other inflammable substances are stored in a Municipal warehouse established under the *Royal Decree of* 4*th July*, 1890, the storage being carried on under the supervision of the Customs, though the premises are leased to a private individual. The Regulations and Tariff are laid down by the *Municipal Regulations of* 4*th September*, 1890. The other substances included in the same regulations are—alcoholic liquids, varnishes, resin-spirit, essential and volatile oils, nitric and sulphuric acids, phosphorus, matches, and inflammable liquids and substances generally.

ROME.

The maximum quantity allowed to be stored inside the town is 120 litres; outside, there is no limit, but all stores must be fireproof, and approved by the Municipal Inspector. Retailers are allowed to keep only 50 litres.

JAMAICA.

Petroleum Laws, No. 23, *of* 1871; *No.* 27, *of* 1882; *and No.* 17, *of* 1893.

The standard flashing point is 95° F. The importation of low-test oil is absolutely prohibited. Retailers must obtain a license from the Justices of the Peace in special session.

Storage Regulations issued by the Governor, 14*th October*, 1886.—Stores must be completely isolated from other buildings or (if adjoining premises are fireproof) completely separated by fireproof walls. Stores must be completely fireproof if within 30 feet of any other building, and properly ventilated to keep the oil at low temperature. Doors must be 3 feet 6 inches wide, opening outwards. Barrels must be stored in rows, one deep and two high against walls, or two deep and two high, away from walls, with a gangway of 4 feet. Cases must be stored two in depth and four in height against walls, or four by four away from walls, leaving 3 feet of passage way. Stores must be used solely for petroleum and kept locked at night and during daytime except when goods are being received or sent out. Lights and smoking are prohibited. Earth or sand should be kept in case of fire.

Testing.—The oil cup is cylindrical, 2½ inches deep and 2 inches in diameter, of tin plate or thin sheet copper, provided with a short spout, a little below the top of the cup, and inclined at an angle of 45°. At about a quarter of the circumference from the spout, and a quarter of an inch from the top of the cup, a metallic pin projects inwards for half an inch. An external flange 1½ inch wide runs round the cup, half an inch below the top, to support the cup in the water bath. This bath is 4½ inches deep and 4½ inches in diameter. The cover of the oil cup is of glass 2¼ inches square. The thermometer is graduated on the Fahrenheit scale—10° occupying at least half an inch. The oil cup is filled to the depth of 2 inches with the oil to be tested, the thermometer inserted through a cork in the spout, so that the bulb is just immersed, and the cup, closed by the glass cover, placed in the water bath, which should be filled to a depth of 2¾ to 3 inches with water at a temperature of 105° to 110° F. When the oil is at 85°, the cover is taken off and replaced, and at 86° is slipped aside, a small light being at the same time applied to the metal pin. If no flash is observed under the glass cover, this is removed, and replaced as before, and the test repeated until a flash is observed. The first result must be confirmed by another test. Care must be taken that currents of air do not interfere with the test, and that the metal pin is free from oil.

JAPAN.

There are practically no legislative restrictions in regard to "test," though decrees effecting classification on this basis have been published. The Government has established warehouses at Nakamura, where all inflammable substances imported into Yokohama have to be stored. The regulations (dated 16th March, 1877) controlling the receiving and delivery of oil, &c., at these warehouses are, in substance, as follows:—The stores are open daily between 8 a.m. and 4 p.m., from 1st October to 31st March, and from 6 a.m. to 6 p.m. during the other months in the year, with the exception of Sundays and certain holidays, on which, however, they may be opened if required, provided that twenty-four hours' notice is given. Applications for storage must be made on a form, accompanied by the Customs' entry and duty receipt, and the director of the store will, after verifying the goods, issue as many deposit certificates as the owner may require. Kerosene oil will not be received at or delivered from the store in smaller quantities than 50 gallons, but this limit does not apply to other substances. An open shed is provided for the soldering, re-filling, and repairing of cases prior to storage. The ownership of goods in store may be transferred by endorsement of the certificate, which must then be countersigned by the director, except where the transfer is in favour of several parties, in which case the original certificate is lodged, and a special transfer form made out in as many copies as there are transferees. Charges must be satisfied before goods can be withdrawn. Sample cases may be taken away after endorsement of the certificate by the director, and when the whole of the goods are withdrawn, the deposit certificate must be returned. One year is the term of storage, and prolongation is only obtained on paying the charges and making a fresh application. When the charges are unpaid, and no application is made for renewal, the Government is empowered to sell the goods, after public advertisement for a month, and to apply the proceeds in satisfaction of charges and expenses, retaining the balance, which, however, will be handed to the owner, less 1 per cent., on production of the deposit certificate. Tank oil is allowed to be kept in special private stores.

JERSEY.

The law at present in force is that of *12th February*, 1891. It relates to oils, mineral and vegetable essences, and allied or derived products, giving off an inflammable vapour below 73° F. (close test). A previous law, passed in 1882, affected only mineral oils and essences, such as petroleum and allied substances, the standard flashing point being also 73° F. The limits of quantity for storage are:—In dwellings, for private use, 5 gallons, without license; or up to 50 gallons in an isolated place approved by the Constable of the parish. For sale, a license (issued for a period of twelve months without charge, by the Constable) stating the name and address of the licensee, description of store, and quantity allowed, is required, the limit of quantity in St. Helier, St. Aubin, George Town, Millbrook, Beaumont Gorey, and Chaussée de Mont-Argueil, being 150 gallons. For larger quantities, in these places, special permission is necessary, and precautions, to be decided upon by the Constable, must be taken for public safety. No testing instrument is mentioned. It is directed that the Constable is to apply the usual tests to ascertain the degree of inflammability. Although the law professedly refers only to substances having a flashing point below 73° F., the storage of high-test oils, in such quantities as might constitute a public danger, is nevertheless prohibited. As in Guernsey, the arrival of cargoes of low-test oil must be notified to the harbour-master, and none may be landed or removed at night. The Constable and Centeniers have the right to search premises and take samples for testing (on payment of their value). Penalties and confiscation are prescribed for infraction of the law.

LAGOS.

The Petroleum Ordinance of 1889 limits the amount to be stored, for use or sale, to 10 gallons, except under license, the conditions of which are to be determined by the Governor. All petroleum on being landed, must be stored in the Government warehouse, whence not less than one case may be removed at one time. Licenses are granted by the Collector of Customs, the cost being 5s. The usual regulations for mooring and unloading vessels; appeal against refusal to grant license; granting of search warrants and penalty for opposing same, are included. No standard of test is prescribed.

MALTA.

Ordinance No. 9 *of* 1889 provides for the testing of petroleum, the standard and the method of testing being the same as those prescribed by the Indian Petroleum Act, 1886, viz.:—76° F. (Abel), or an average of 73°, provided no sample flashes below 70°. Notice must be given to harbour officials on the arrival of a cargo of petroleum, so that the collector of customs may take samples for testing. Appeal against the inspector's test is decided by a skilled person appointed by the Court. The superintendent may order the ship containing low-test oil to be removed to another port in the island, or to a distance of 1 mile from the shore.

MAURITIUS.

Ordinance No. 10 *of* 1872.

The importation, selling, or keeping of all descriptions of petroleum giving off an inflammable vapour at less than 100° F. (open flash test) is prohibited under penalty of fine and confiscation. Inspectors of licenses, officers of customs, and officers of municipal corporations have powers of inspection, sampling, and testing; but the owner of the oil can appeal, in which event, the decision of the government analyst, or of a competent person appointed by the magistrate, shall be final. If seizure is made, and the goods are restored to the owner, the magistrate, if of opinion there were reasonable grounds for the seizure, shall grant a certificate to that effect, which shall be a bar to proceedings against the inspector.

MONTSERRAT.

Petroleum Ordinance, 1892.

Standard of test, 83° F. (Abel). Limit of quantity to be stored, 50 gallons. All larger quantities must be kept in the Government petroleum warehouse. No low-test oil allowed to be imported, except gasoline for scientific or technical work (by permission of the Governor) and oil in 8-oz. bottles not intended for burning. Oil ascertained to be low-test, may be re-shipped under certain conditions, otherwise it is liable to forfeiture. Inspectors are appointed by the Governor.

NATAL.

In this colony, there are no Government regulations for the storage, &c., of petroleum. In Durban and Pietermaritzburg, there are Municipal bye-laws relating to the subject, and outside the former town the

Municipal Council has granted a piece of land for the building of petroleum stores by applicants, from which stores the places of business in the town are supplied. DURBAN (*General Bye-laws, section* 43).—No person may keep or store, unless under license from the Council, more than 20 gallons of petroleum, kerosene, paraffin, or any other mineral oil, within 100 yards of any dwelling-house or warehouse, under penalty of £5 per day. The Council may authorise the searching of suspected premises, and any one obstructing the search is liable to fine. The conditions of license are in the hands of the Council. PIETERMARITZBURG (*General Bye-laws, section* 188).—No person shall keep, within the city, more than 100 gallons of petroleum oil, kerosene, or any other mineral oil, within 100 yards of any dwelling or warehouse.

NEVIS AND ST. KITTS.

Gunpowder and Petroleum Ordinances, 1878 *and* 1892.

Standard test 83° F. (Abel). Limits of quantity to be stored:—10 gallons for private use, and 20 gallons for sale under license; larger quantities in places specially appointed by the Governor. The remaining provisions are similar to those in force in Montserrat.

NEWFOUNDLAND.

The Kerosene Act, 1890, limits the quantity of any inflammable oil to be kept on board any boat, ship, raft, shed, or other place in the harbours of St. John's, Harbor Grace, Carbonear or Brigus, to 5 gallons, but this does not apply to oils in course of, or awaiting, shipment or discharge.

NEW BRUNSWICK.

The regulations in St. John, are contained in the *Petroleum Storage Act, 23rd April*, 1890. 250 gallons is the maximum quantity to be kept (in not more than 5 barrels or vessels), except in a store erected under the provisions of the Act of 34 Vic., c. 33. It is also forbidden to allow such oil to remain on any open or uncovered piece of land for more than twenty-four hours, or longer than six days on any wharf in the city. The Chief Engineer of the Fire Department and the Engineer of the Public Safety Department, are appointed inspectors of stores, with right of entry during reasonable hours.

NEW SOUTH WALES—*See* AUSTRALIAN COLONIES.

NEW ZEALAND—*See* AUSTRALIAN COLONIES.

NORTH BORNEO.

The *Explosive and Combustible Substance Storage Proclamation*, 1884, limits the amount of petroleum to be kept in any *attap* tenement, to 12 *catties*[1] (and that for private consumption only), and in any other building or place, 1 tin of 25 *catties*, except under special permit, from the Resident, in the town of Sandakan, and from the Governor elsewhere, stating the amount allowed to be stored. The Governor may also make regulations for depôts, and authorise charges for storage. A permit is required before removal from any place or vessel to any other place or vessel. There is no standard of test.

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[1] A *catty* = 1·3948 lb. avoirdupois.

NORWAY.

In 1871, a legislative enactment (dated 3rd May) provided regulations for the storage of petroleum and its products. The liquids were divided into two classes, according to their degree of inflammability. Under Class A were included ether, photogen, camphine, benzene, "gas ether," carbon bisulphide, petroleum naphtha, petroleum spirit, and all petroleum and turpentine products giving off an inflammable vapour below 35° C. Class B consisted of those mineral oils, &c., having a flashing point not below 35° C. The erection and carrying on of refineries for inflammable liquids was only permitted outside the boundaries of towns and at a minimum distance of 400 feet therefrom, and it was required that there should be a minimum distance of 200 feet between a refinery and the nearest building. The prevention of outflow of dangerous liquids was also insisted on. Crude and refined petroleum, and crude paraffin oil, were placed on the same footing as regarded restrictions in respect to storage, but chemists were allowed to keep up to 3 gallons of crude oil, in vessels holding at most three-quarters of a gallon. The quantity to be stored in any one building, was limited to 30 gallons of liquids of Class A and 200 gallons of liquids of Class B. Larger quantities (up to 2,500 gallons of Class A and 125 gallons of Class B) were allowed to be stored in underground cellars, sufficiently large to prevent outflow, made of fireproof materials, with iron doors, and well ventilated. Ships carrying passengers were not allowed to have more than 15 gallons of liquids of Class A on board. For the unloading of ships and the transport of crude oil, notice to the police was necessary. The fixing of the standard of test and mode of testing was vested in the King.

In 1879, a fire test (of 120° F.) was substituted for the flash test, but no instrument for determining the fire test was ever prescribed by the King, and it was not until 1890 that a definite standard was introduced. By the law of *14th June* of that year, 22° C. (Abel), at a barometric pressure of 760 mm., is fixed as the minimum flashing point for liquids of Class B, all flashing at a lower temperature being included in Class A. The quantities now allowed to be stored in one building or store-ship, are :—

Class A. 360 litres, in vessels marked "dangerous," and holding not more than 15 litres each.
Class B. 800 litres; or larger quantities under special permit.

Stores are to be at a distance of 125 metres from the boundaries of towns. It is forbidden to transfer liquids of Class A from one vessel to another within town boundaries, and persons dealing in or wishing to land liquids of this class must notify the police.

PERAK.

Order in Council, No. 4, 1889.

No person may keep more than 2 cases (16 gallons) of petroleum, except in the Government stores. There is no standard of test definitely mentioned, nor regulations for testing, but it is provided that—

> "No person shall bring into the State any petroleum from any place other than one of the ports of the Straits Settlements, and which has not conformed to the standard test in force in such port."

So that, practically, the standard is the same as for the Straits Settlements, viz., 71° F. (Abel). All police officers above the rank of sergeant may act as inspectors of stores.

PORTUGAL.

Decree of 21*st October,* 1863.

The storage, in depôts, of more than 50 kilos. of inflammable liquids (alcoholic and ethereal liquids, spirits of turpentine, petroleum, &c.), and, in cities, the storage of such liquids in any place where drugs and other articles are also kept, is subject to the supervision of the police.

There are no fixed regulations relating to storage, but the administrative authorities, after consultation with experts, may impose such restrictions as they may think fit. The *Preliminary Instructions of The General Customs Tariff,* 14*th December,* 1882 (11*th paragraph of Art.* 14 *and Schedule* C), provide that all mineral oils and spirits may only be landed at special quays, whence they are conveyed to the stores.

QUEENSLAND—*See* AUSTRALIAN COLONIES.

RUSSIA.

"*Temporary Regulations*" *of June,* 1867.

Stores are divided into—

Large—Containing 150 *poods*[1] and upwards.

Small—Containing from 30 to 150 *poods.*

Retail—Below the limit assigned above for a "small" store.

A distance of not less than 25 fathoms must separate stores. *Large* stores are only permitted outside a town, and at a distance of not less than 50 fathoms from any building. *Small* stores of oil may be constructed in towns and villages, not nearer than 20 fathoms from buildings, wood yards, timber and flax warehouses, and inflammable substances generally. *Retail* stores are allowed in shops, except in bazaars and market places, on condition that there are not, in the same place, any other highly inflammable substances—*i.e.*, gunpowder, matches, turpentine, &c. In the large and small stores, no other material is to be kept. In general, the site for the erection of stores is to be chosen by the local police, and their preliminary permission is required. The regulations as to large stores are applicable to places for the refining of petroleum and mineral oils generally. Tobacco smoking, the kindling of fire, and the heating of tea urns, are forbidden in large and small stores, as well as in places where mineral oil is stored for retail sale. Stoves are permitted in the shops, but not in the places where the oil is stored. Such places may, however, be heated by pipes. Places of wholesale storage, sale, and refining are to be indicated by signboards. Large and small stores must be in separate buildings of brick or earth—the latter may consist of wooden huts covered with a layer of earth and bark, or an underground cellar with the same covering, but the only access to such cellar must be through the door. The floor of the cellar must be of stone or earth, and of concave shape, with a reservoir to catch leakage. Stores must be ventilated. In shops, the oil may be kept only in arched brickwork cellars of houses having an iron roof, with a stone or earthen floor; the doors and netting at the windows to be of iron, and place to be ventilated. Uncasking of oil at stores and shops, and delivery of same, may be effected only during daytime, and no one may enter stores with candle, lamp, or other light; but in cases of special need a safety lantern may be used. In stores, the petroleum may be kept in wooden or metallic vessels. In shops, the oil may be kept and conveyed to and from shop only in metallic vessels, containing not more than 1 *pood.* The oil must not be kept or sold in earthenware or glass vessels. Buyers are to provide themselves with strong metallic vessels with corks. Empty barrels may not be kept at shops or stores. Barrels at large permanent stores must not be heaped together, but placed at a distance of 5 fathoms apart. The standard of test is 28° C. (Abel-Pensky).

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[1] A *pood* = 36·1127 lbs. avoirdupois.

SAINT LUCIA.

Petroleum Ordinances of 1875 *and* 1881.

Standard of test 95° F. (close test, applied as in Jamaica). No oil is allowed to be sold except under license, to be obtained from the Stipendiary Justices. The Governor may grant a license after the refusal of the Justices. Limits of quantity to be stored :—On private premises for consumption, 10 gallons; in licensed stores, 100 gallons. For larger quantities, stores must be provided under regulations made by the Governor. The sale of low-test oil for burning, is absolutely prohibited, but such oil may be sold for other purposes, in 8-ounce closed bottles. Contravention of this provision involves forfeiture. Appeal against the inspector's test is decided by a "medical" officer appointed by the Justices. Search warrants for suspected premises may be issued.

SIERRA LEONE.

Petroleum Ordinance, 1882.

Standard of test 95° F. (open cup). All petroleum over 5 gallons, for private use, must be kept in the Government store (whence not less than 10 gallons may be removed at a time), or on premises duly licensed by Justices of the Peace. There are the usual provisions respecting low-test oil, landing, notice by master on arrival of vessel, search under warrant, obstruction of inspector, and appeal against test. Provisions respecting hawking are similar to those of English Act, 1881; limit of quantity, 10 gallons.

SOUTH AUSTRALIA—*See* AUSTRALIAN COLONIES.

SPAIN.

There is no general law as to the storage, &c., of mineral oil and spirit. The manufacture and storage of these articles (together with explosives and articles of an inflammable character) are regulated by municipal byelaws, of which those in force in Madrid are said to afford a fair example. The Madrid bye-laws do not mention mineral oil or spirit, but they specify fireworks, gunpowder, phosphorus, pitch, tar, resin, gum, and brandy, and they provide that these substances and all other inflammable articles (presumably including mineral oil and spirit) may be kept only under license, in vaulted and properly constructed cellars, and in quantities not exceeding a month's sale. Stores for large quantities, and for wood, coal, firewood, and straw, and similar materials burning easily, shall be situated, "if possible," in isolated places and out of the town, and the premises must be licensed. Insurance companies may inform against any infraction. The stores may not be entered during the night, even with a properly closed lamp, and no smoking or artificial light is allowed in stores where brandy, coal, straw, or phosphorus are kept.

STRAITS SETTLEMENTS.

Ordinances No. XII., 1883; *No. XVIII.*, 1886; *and No. IV.*, 1892. *Government Notifications and Orders in Council,* 12*th Dec.*, 1883; 15*th May and* 22*nd May*, 1885; 26*th May*, 1887; 10*th Aug.*, 1892; *and* 2*nd Dec.*, 1892.

No more than 4 cases of 8 gallons—or 32 gallons in all—may be kept without a license, which may be granted up to the amount of 20 cases by the Municipal Commissioners.[1] Beyond 20 cases, the Governor's approval is necessary. The Governor is empowered to fix a standard of test by order in Council, and no "dangerous" oil may be imported or kept, under penalty of fine and confiscation. Importers must inform inspector of arrival of cargoes. Inspectors have right of searching suspected premises, and resistance is punishable by fine. In towns, inspectors of nuisances, and in other places police inspectors, are *ex-officio* petroleum inspectors.

MUNICIPAL REGULATIONS FOR STORAGE OF NOT MORE THAN 20 CASES OF PETROLEUM IN THE TOWN OF MALACCA.

Government Notification, 438. *Singapore*, 10*th August*, 1892.

1. Licenses are not granted for wooden houses. 2. A brick, stone, or iron receptacle, or bin, 5 ft. 4 in. by 4 ft. 4 in. by 2 ft. 6 in. deep,

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[1] In Singapore, Georgetown, Penang, or Malacca; and in other places by the Chief Officer of Police.

must be provided on the premises before a license can be obtained, and at least 4 "pikuls" of sand must be kept close at hand in case of fire. Petroleum may be kept only within this receptacle, and no other goods may be stored therein or upon the same. No fire or cooking stove is allowed within 10 feet. Not more than 4 cases may be exposed for sale at a time, and all must be kept in the bin during the night. Not less than a whole tin may be sold after dark.

The regulations affecting the discharge of petroleum from import vessels (26th May, 1887) are to the effect that "dangerous" petroleum shall not be brought into a port, but shall be landed and stored as the Governor directs, under guarantee from the owner or master that it will only be dealt with according to the Act of 1883. Landing must be effected in daylight only, no lamps or lights being allowed near the holds, and must be carried on under the supervision of the police, at the owner's expense. The Government may sell the oil in order to defray expenses and penalties incurred. The standard of test (fixed by order in Council, 15th May, 1883) is an average of 71° F. (Abel), provided no sample in a cargo flashes below 69°. Notice must be given to the harbour-master on arrival of vessel, and no oil must be landed until the inspector has tested samples and made his report.

SWEDEN.

Laws of 26th November, 1875, *and 27th March*, 1885.

The inflammable liquids affected by these regulations are divided into two classes. Class I. comprises the more inflammable—such as benzine, ligroïn, petroleum, naphtha, crude paraffin oil, crude wood spirit, &c., giving off an inflammable vapour below 22° C. (= 71·6° F.) Abel test. Class II. includes all the less inflammable, viz., refined petroleum, refined paraffin oil, astral oil, refined wood spirit, turpentine, lubricating oils, &c., flashing between 22° and 40° C. (= 104° F.) Abel test.[1] Refineries must be at least 500 feet (about 487 feet English) from the boundary of a town, or from any other building, unless by special permission. Plans of the works must be submitted to the authorities, and the premises inspected, before refining is begun. Provision must be made for the prevention of outflow or drainage of oil into other properties or into canals, lakes, &c., and all oils must be removed from the premises as soon as ready for market. *Storage.*—Both the wholesale and retail stores are subdivided into two classes. *Smaller wholesale stores* are for quantities of 2,000 to 35,000 *kannor* (1,152 to 20,160 gallons)—or, with special permission, 70,000 *kannor* (40,320 gallons)—not more than 7,000 *kannor* of which shall be of liquids of Class I., but such stores must not be in a closely built or inhabited part of a town, nor under a building used for any other purpose. *Larger wholesale stores* are not subject to any restriction as to quantity, but cannot be established without special permission.

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[1] The standard flashing points mentioned were fixed in 1885. Previously the standards were—

For Class I., 35° C. (= 95° F.).
" " II., 80° C. (= 176° F.).

The limits of distance from other buildings, &c., and prohibition of risk of outflow, are the same as for refineries. Every wholesale store is required to be well ventilated, and to contain an excavation, kept free from water, and large enough to hold one-fourth more than the entire quantity stored. If within the 500-feet limit and above ground, the store must be built with fireproof brick, or iron walls with iron doors and windows. No smoking, matches, or lights are allowed, and work may only be carried on during daylight. No part of the store may be used as a dwelling place at night. Sand must be provided in case of fire. Only iron barrels or wooden casks with iron hoops may be stored, and these must be so arranged as to admit of ready inspection. No more empties are allowed to be kept than are absolutely necessary.

Small retail stores.—Permission is granted on giving notice. Limit, 300 *kannor* (about 173 gallons), of which not more than 30 *kannor* (about 17 gallons) may be of liquids of Class I. Stock to be kept in 10-gallon (maximum) iron casks, or 3-gallon glass or stone bottles. *Large retail stores.*—Permission is granted after inspection and approval of premises. Limit of quantity, 2,000 *kannor* (1,152 gallons), including a maximum of 400 *kannor* (about 230 gallons) of liquids of Class I. Precautions must be taken against fire, and the authorities may prescribe additional regulations. *Private houses.*—Limit of quantity, 20 *kannor* in towns or 100 *kannor* in the country. A sufficient number of inspectors shall be appointed by the head of the Civil Department of the Government, each inspector to be provided with an Abel tester, and to keep a record of all tests.

SWITZERLAND.

Regulations in the Swiss Confederation are local only, each Canton having its special laws governing the storage and sale of petroleum and other inflammable substances, except Schwyz and Argovie. Zurich is the only one where a standard of test is specified.

Appenzell—Rhodes Extérieures.

A regulation dealing with the distillation and storage of inflammable and volatile substances, was prefixed in 1871 to the existing law for the prevention of conflagrations. No limit of flashing point is mentioned in this regulation, but the following substances are particularly referred to:—Petroleum, "ligroïn," and other volatile and inflammable liquids and materials. Section 9 of the regulation says—for purposes of private use, not more than 5 kilos. of petroleum or half a kilo. of ligroïn may be kept. In magazines which are situated in the fire brigade district, or at less than 200 feet distance from another building, there is never allowed to be stored more than 10 barrels of petroleum or 15 kilos. of ligroïn. No single receptacle for ligroïn should contain over 1½ kilo. Larger quantities of petroleum, ligroïn, and the like, must be kept in isolated magazines, at least 200 feet distant from other buildings. The establishment of these magazines is subject to the approval of the local fire police. The roof must be of lead, tiles, or other hard material; shingles must not be used for it. The magazines must be entirely enclosed, and provided with ventilators, which can be closed from the outside. The distillation of these oils may only be effected in fireproof rooms, under the same conditions as to isolation, &c., as the foregoing. Smaller quantities of petroleum and ligroïn must similarly be kept in fireproof places, and never in glass receptacles. The sale and handling of these oils in the night-time is forbidden. The use of open or closed lanterns, &c., smoking, and especially any employment of fire, are forbidden in all the above-mentioned magazines and rooms. A supply of sand is to be kept at hand in each case. Similar precautions, as to the proximity of fire or lights, are to be taken in all places where retail dealing in these oils is carried on.

CANTON OF BERNE.

Ordinance of 12*th June*, 1865.

In this Canton, mineral oils (liquid bitumen, naphtha, and petroleum) and all similar liquids, and their derivatives, are subject to the same regulations as (*a*) spirits of wine (25° to 40° Cartier); essential oils, such as turpentine, varnishes containing spirits of wine or turpentine; (*b*) carbon bisulphide, ether and ethereal liquids, collodion, benzene, and absolute alcohol[1]; (*c*) phosphorus; (*d*) gun-cotton; (*e*) fulminating silver, and fulminating mercury.

The limits of quantities to be stored in or near dwelling-houses, is as follows:—(*a*) 1 barrel, as understood in the wholesale trade; (*b*) 3 lbs. (Swiss); (*c* and *d*) 2 lbs. (Swiss); (*e*) $\frac{1}{8}$ lb. (Swiss). Such stores must be registered at the police office of the district. All quantities beyond those required for current daily sale must be kept in cellars, well lighted by daylight and only accessible to the proprietor, or his *employés*, on his personal responsibility, and contained in stout vessels of glass, stone, or metal, protected from heat by a covering of straw or other material, or in strong casks. The storage and sale of unrefined mineral oils (naphtha, shale oil, petroleum, photogen and solar oil) or similar liquids in any quantity whatsoever, in or near dwelling-houses, is prohibited except under the following conditions:—Permission must be obtained in accordance with article 14, 3, *h*, and article 24, *et seq.*, of the Industrial Law of 7th November, 1849, and this is only to be granted after official inspection and approval of the premises. Manufactories, refineries, &c., are also subject to the same conditions (article 14, 3, *g*, Industrial Law, 1849) with the exception of pharmacies for medicinal preparations. All the substances under this ordinance, except spirits of wine, must be sold by weight only, not by measure, and may be weighed or manipulated only in daylight. No matches, lights, or smoking are allowed. Mineral oil lamps must not be used for lighting barns, stables, granaries, &c. The carrying out of these provisions rests with the Prefects, who must have all premises concerned thoroughly examined by experts. The police authorities must also make at least one inspection annually.

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[1] Nitric acid and hydrochloric acid are also included under (*b*).

GENEVA.

Notification by the Department of Justice and Police, 8th December, 1876.

A distinction is made in the regulations laid down by the Government of this Canton, between petroleum and "petroleïn," "neolin," and analogous substances. Wholesale dealers in petroleum may store up to three barrels of the liquid in their private magazines. These must be constructed either on a ground floor or in a cellar, and must be strongly built, easy of access, well ventilated, &c. A supply of sand must be kept in readiness. Retail dealers may store in their shops a single barrel of 175 kilos. gross weight. Private persons may keep a quantity not exceeding 10 kilos.

As regards petroleïn, wholesale dealers are not permitted to store over 100 kilos. in their magazines. Special precautions must be taken against accidents, and all transactions must take place by day. The use even of safety lamps is forbidden. A retail dealer is limited to a supply of 50 kilos. at most, to be kept in an outhouse. All operations—changing of vessels, &c.—must be carried on in the open air, and by day. The liquid must be kept in metal bottles, of half a litre or a litre, broad at the bottom, not entirely filled, and tightly corked. Each of these receptacles must bear the guaranty of the department of police. In the actual shops, a limited number of these bottles may be kept, representing, in all, 25 litres. Private persons may store 1 litre of petroleïn.

Authority to store must be obtained from the Department of Justice and Police, and will be granted on the foregoing conditions. No casks or vessels containing petroleum and its products may be left in the street or in courts or alleys. The Department may order its officers to inspect stores and test their contents; obstructing the officers, or any contravention of these regulations, is punishable by fine and withdrawal of permission to store.

LUCERNE.

Trading in crude petroleum, or similar substances, is placed under police supervision. This applies to all substances which are inflammable below 35° Réaumur, whether they be entirely crude or partially refined. In private houses, no greater quantity than 5 half-gallons, is permitted to be kept; in shops or private storehouses, up to 200 lbs. may be stored. In the latter case, metal receptacles must be employed, those not in actual use being embedded in sand or earth. Greater quantities may be stored only in roofed cellars or caverns, outside the limits of any town, and at a convenient distance from any tenements. These are to be approved by the police, and substances which are not explosive may, during the preparation of such receptacle for storage, be temporarily placed in a public magazine. The aforesaid cellars are to be duly ventilated, the flooring to incline towards a central sink reaching to the clay subsoil. Sand must be laid down to the depth of 6 inches. The door should be lower than the surface of the surrounding earth, and no outfall into a river or canal is allowed. All work must be done by day, and no artificial light may be at any time introduced. A plentiful supply of sand must be kept in readiness.

ZURICH.

Petroleum and Inflammable Substances Ordinances, 14th April, 1880, and 27th July, 1888.

The storage, transport, and sale of petroleum, benzene, ether, oil of turpentine, neolin, ligroïn, and other inflammable substances, including spirit and turpentine varnishes, as well as the sale of petroleum lamps and cooking stoves, are placed under police supervision.

No oil of a flashing point below 23° C. may be used for petroleum lamps and cooking stoves; neolin and ligroïn may not be supplied for private use, but may be employed for lighting public streets and squares, under the supervision of competent persons. The only lamps which may be sold are those in which the constant temperature of the oil when the lamp is burning does not exceed that of the external air by more than 5° C. Stoves must be of special construction, and both lamps and stoves must admit of being readily cleaned. Vendors of lamps and stoves must show their stock to the police, and furnish samples for examination, when required. Storage in the open air is prohibited. The following are the maximum quantities allowed to be stored:—

SUBSTANCE.	QUANTITIES.		
	For Private Use.	In Retail Shop.	In Shopkeeper's Private Store.
Ether, ...	None allowed.	None allowed.	**50 kilos.**
Carbon bisulphide, . .	,, ,,	,, ,,	**50 ,,**
Neolin or Ligroïn, . .	,, ,,	,, ,,	**50 ,,**
Benzene, ...	5 kilos.	25 kilos.	**50 ,,**
Crude petroleum, . . .	None.	None.	**50 ,,**
Wood spirit, . . .	,,	,,	**100 litres.**
Spirit of Wine, . . .	5 kilos.	50 litres.	**700 ,,**
Refined petroleum (flashing point not below 23° C.), .	10 ,,	150 kilos.	**5 barrels of 150 kilos.**
"Safety Oil" (flashing point not below 31° C.), . .	10 ,,	150 ,,	
Oil of Turpentine, . .	5 ,,	50 ,,	**3 barrels of 150 kilos.**
Spirit or Turpentine Varnish,	5 ,,	50 ,,	**200 kilos.**

All quantities in excess of those in the last column, must be kept in special fireproof magazines. In shops, only metal vessels with brass taps and drainers to catch the droppings, are allowed for petroleum and benzene. They must be plainly labelled and kept at a distance from stoves or direct light, and may only be filled during daylight. Empty barrels must be stored so as not to increase the risk of fire, and notice of their being on the premises must be given to the fire police.

Shopkeepers' stores must be fireproof, well ventilated, and isolated from the interior of the house, or from other stores, and none of the leakage from the storage vessels must be allowed to run into any river, canal, or sewer, neither may there be any gas or heating apparatus.

Sand must be provided to quench fire. Smoking, and the use of artificial light, except a safety lamp, is forbidden, and entry into the store is only allowed under supervision of the manager.

Larger Stores.—These must be erected outside towns or villages, away from buildings or streets, and at distances fixed by local authorities. They must be fireproof, easily accessible, well ventilated, and so arranged that, even during floods or heavy rainfall, none of the liquids stored can be carried into rivers, canals, or ditches. Sand must be provided in case of fire. If the store is above ground, it must not be of more than one storey, and must be surrounded by a continuous wall of earth or stone 1 metre high and 3 metres from the wall of the store, or by a trench 3 metres wide and 1 metre deep. The floor of the store must be of impermeable material and inclined towards a well. Stores may also be underground, in which case they must be fireproof, built of strong masonry, or cut in the rock, and have tightly-closing doors and windows. If in the rock, so that a wall or ditch cannot be made all round the store, and unless the floor is sufficiently below the outside level, then a wall or ditch large enough to prevent any outflow, must be made round the doorway. If there is another storage room built over the cellar, there must be no internal communication between them, and they must be so arranged as to prevent the possibility of damage to the upper storey by the outbreak of flames from the lower.

TASMANIA—*See* AUSTRALIAN COLONIES.

TRINIDAD.

Petroleum Ordinances of 1872 (*No.* 6) *and* 1874 (*No.* 14).

Vessels carrying petroleum as whole or part cargo must, while in the harbours of San Fernando or Port of Spain, conform to the harbour master's regulations, under penalty. The Governor may appoint storage places in or within one mile of Port of Spain and San Fernando, and make regulations for landing and keeping. No petroleum may be delivered from places so appointed except between 8 a.m. and 3 p.m. (for licensed stores, the hours are 7 a.m. to 6 p.m.) For the storage of all quantities over 10 gallons, a license is required, and the oil must be in uninflammable receptacles. (The Ordinance of 1872 limited the quantity under license to 50 gallons.) Breach of these regulations is punishable by fines and confiscation of the oil. Powers of search, under warrant from the Inspector Commandant, are given, and sampling and testing by competent person, are provided for.

TURKEY.

There are no testing regulations. The oil is stored in and retailed from a Government depôt on the Bosphorus.

UNITED STATES.

Note.—All temperatures under this heading are in degrees Fahrenheit.

ALABAMA.—There is no State law referring to petroleum products.

City of Mobile.—The storage of petroleum and other inflammable liquids is under the control of the Fire Police Department.

ARIZONA.—No State law relative to petroleum.

ARKANSAS.—*Storage.*—No State regulations. *Test.*—130° fire; Tagliabue cup.

CALIFORNIA.—No State law on petroleum.

City of Los Angeles (1883).—*Storage.*—Except in one specified district (District No. 3 of the general fire limits of the city) not more than 150 gallons of any petroleum product other than refined petroleum (for which the limit is 200 gallons in metal cases) may be kept, and this must be stored in iron tanks. No license necessary. *Test.*—110° flash; Tagliabue open cup.

City of Sacramento.—*Storage.*—Same as San Francisco (*q.v.*). *Test.*—110° flash; Tagliabue open cup.

City of San Francisco.—*Storage.*—For quantities in excess of 100 gallons of spirit or 1,000 gallons of oil (both in metal cases) an annual license must be taken out, and the stores must be brick buildings not over one storey high, used for no other purpose, and approved by the fire marshal and majority of fire department. *Test.*—100° flash; Tagliabue open cup.

CAROLINA.—See North Carolina and South Carolina.

COLORADO.—The power of making petroleum regulations is vested in mayors and councils of cities and towns. There is no State law referring to test.

City of Denver.—*Storage.*—A permit from the mayor is necessary in the case of storage of more than 3 gallons of mineral spirit or 5 barrels of refined petroleum within the city limits. *Test.*—110° flash; Tagliabue open cup.

COLUMBIA (District of).—*Test.*—No oil, or any fluid made from petroleum or its products, flashing below 120° F. may be stored.

CONNECTICUT.—No State law affecting storage. *Test.*—110° fire.

City of Meriden.—*Storage.*—Annual license. Limit, 3 barrels in any inhabited building, or 10 barrels in cellars 4 feet below ground level, and not under a dwelling. *Test.*—125° fire.

City of Newhaven.—*Storage.*—Permit or license required for quantities exceeding 1 barrel of refined oil. Up to 3 barrels, a permit from the fire marshal is sufficient. Beyond this amount, and up to 30 barrels, storage is allowed, under Corporation license, in cellars 5 feet below the ground, or with a raised sill of 3 feet of masonry (with a limit of 10 gallons in the case of spirit). For larger quantities, special provisions are requisite. No refinery may be erected within 300 feet of any building, wharf, bridge, or body of water communicating with Newhaven harbour. *Test.*—11[illegible]re; Tagliabue cup.

DAKOTA.—[illegible] Dakota and South Dakota.

DELAWARE.—There is no law concerning the testing or storage of petroleum products.

City of Wilmington.—In certain defined districts of the city, only as much as 5 barrels may be stored, but outside these localities, an unlimited quantity may be kept, provided that the place of storage is at a minimum distance of 100 feet from any dwelling. *Test.*—110° fire.

FLORIDA.—*Test.*—130° fire; Tagliabue cup.

GEORGIA.—*Test.*—120° fire.

City of Savannah (1881).—*Storage.*—Up to 250 gallons may be kept in any building without a license; or an unlimited quantity in specially adapted detached buildings (not occupied as dwellings), constructed so as to prevent outflow, and either situated at least 50 feet distant from any other building, or separated therefrom by a wall 10 feet high and 12 inches thick. Licenses are granted to store on other premises, except wharves and dwellings, or rooms above the ground floor, provided the parting walls and all doors are fireproof.

IDAHO.—There is no State law referring to petroleum.

ILLINOIS.—*Storage.*—No State law. *Inspection* (*State Law*, 1*st July*, 1877).—The appointment of testing inspectors in towns and villages, is compulsory on the requisition of more than five inhabitants. Inspectors must brand all casks, &c., tested, with "approved fire test . . ." if the oil passes the test, otherwise with "condemned for illuminating purposes, fire test being . . ." A record of tests must be kept, and this is to be open to inspection. Producers of or dealers in oils must give notice to the inspector within two days after oil is made, refined, or received. Omission to do this; selling untested or low-test oil; counterfeiting brands; or using branded vessels for untested oils; is punishable by fines and forfeiture of the oil, as well as liability for damages to any one injured. Inspectors may not trade in oils, and are liable to dismissal, fine, and damages for any injuries resulting from any fraud or negligence, of which they may be guilty. *Test.*—150° fire; Tagliabue cup, or other approved instrument.

City of Chicago.—*Storage.*—The limit of quantity which may be kept without license, is 5 barrels of mineral spirit or turpentine, of which not more than 1 barrel may be stored elsewhere than in a celler 5 feet below the level of the street. The 1-barrel limit elsewhere than in a cellar, applies also to refined petroleum. Unlimited quantities may be stored—subject to license from the Corporation—in detached fire-proof warehouses exclusively used for inflammable liquids, provided that these are properly ventilated, situated at least 50 feet from other buildings, and having cellars at least 3 feet below the ground floor. The walls must be at least 16 inches thick, and not exceed 16 feet in height; the floors must be made fireproof, and the roofs of iron or composition. The surrounding fire-walls are to be of specified height and thickness, and the copings of incombustible material.

City of Peoria.—*Storage.*—Retailers may store up to 2 barrels outside the fire limits without license. Larger quantities must be kept in specially constructed buildings or closed tanks, at least 40 feet from other buildings, and by special permission, as to amount, from the chief of the fire brigade and the city council. The principal details of construction of these buildings and tanks are, that the former must have walls of masonry of a minimum thickness of 16 inches, and a maximum height of 18 feet, and the tanks are not to exceed 20 feet in height or diameter. The latter are to be fitted with automatic safety-valves, to stand 30 feet apart, and to be contained in walled enclosures of at least three-quarters the capacity of the tanks.

INDIANA.—*Test.*—120° flash; Indiana cup. *Storage.*—No State law. The local regulations in all the chief cities are similar to those of Philadelphia (*q.v.*).

INDIAN TERRITORY.—No law on petroleum.

IOWA.—*Test.*—105° flash; Elliott cup. *Storage.*—No State laws. *Inspection.*—The appointment of inspectors and deputy inspectors to test the oil is compulsory. The provisions are similar to those in force in Wisconsin (*q.v.*).

KANSAS (*Law,* 18*th March,* 1889).—*Inspection.*—Appointment of inspectors is provided for, as in Illinois. Inspector must give bond for proper discharge of duties; and brand standard test oils:—"approved, fire test being 110°;" and low-test oils:—"condemned for illuminating purposes, fire test being below 110°;" together with name and date. Inspector may appoint deputies, for whom he is responsible, but may not deal in oils. He must keep a record of tests, open for inspection. In case of fraud, or culpable negligence in discharging his duties, an inspector is liable to fine and imprisonment. Selling low-test or untested oil; falsification of brands; omission to give notice to inspector of possession of untested oil within two days after same is made or received; or using branded vessels for untested oil, is punishable by fine and confiscation of the oil. *Test.*—110° fire; Tagliabue cup. *Storage.*—No State laws.

CITY OF TOPEKA.—The storage of quantities exceeding 5 barrels, is subject to permission by the fire marshal, who regulates the construction of stores and is required to regularly inspect them.

KENTUCKY.—*Storage.*—No regulations. *Test*[1] (Law of 21st February, 1874).—130° fire. Oils passing the test are to be branded "standard oil," and all others are to be marked "unsafe for illuminating purposes." The selling of uninspected or low-test oil, or the hindering of inspectors in the discharge of their duties, is punishable by fines. By the Law of 8th February, 1876, inspectors are appointed for four years. *Regulations for Applying Fire Test* (Law of 21st February, 1874).—Water cup must contain sufficient water to reach two-thirds of the way up the side of the oil cup, which is to be filled with oil to within $\frac{1}{8}$ inch of the top. If the oil does not ignite without heating when a lighted match is applied to its surface, an alcohol lamp is used to raise its temperature, and is so regulated that the temperature of oil increases between 1° and 2° (minimum and maximum limits) per minute, as indicated by a thermometer, the bulb of which is just covered by the oil. At each degree, a lighted match is passed over the surface of the oil at a distance of $\frac{3}{8}$ inch, and as soon as the oil flashes, the lamp is removed. If it does not continue to burn, the test is continued as before until ignition takes place.

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[1] See *General State Laws,* J. B. Sanborn, 1878, chap. cxxii.

City of Louisville.—The General Council has power to introduce storage regulations, but does not appear to have acted upon it.

LOUISIANA.—*Storage.*—There is no State law on this head. *Inspection* (Law of 2nd April, 1877).—Inspectors must test, gauge, and mark each barrel, and deliver a certificate to the owner, taking a duplicate for the Board of Health. This does not apply to oil for delivery outside the State, which must be so branded by the seller. No untested oil or naphtha may be sold, and if sold, the seller is debarred from any suit at law to recover price of same from the purchaser. Low-test oil must be marked "explosive and dangerous," failing which, the seller, besides being liable to penalty, is also liable in damages and costs, for injury to persons or property caused by explosion or ignition of such oil, except in case of gross negligence or carelessness. *Test.*—125° flash; Tagliabue or other approved instrument.

City of New Orleans.—*Test.*—110° fire; Tagliabue cup. *Storage.*—The quantity of oil that may be stored in one building, is limited to 5 barrels (or the equivalent), and it must be contained in metallic packages.

MAINE.—*Storage.*—No law. *Test.*—120° flash; Tagliabue open cup.

City of Portland (1883).—A license is required for quantities exceeding 100 gallons, but may not be granted for storage at wharves or on inhabited premises, or for storage above the first floor of any building, or for keeping spirit elsewhere than in cellars, unless contained in well-closed metal vessels. Neither may more than 100 gallons of any petroleum product be kept on the first floor, unless contained in tightly-closed metal vessels, and the foundations and walls of the building are of stone, brick, or iron, and the walls built without apertures for at least 1 foot above the floor. The corporation has power to revoke licenses at pleasure.

MARYLAND.—No State law relating to petroleum.

City of Baltimore.—*Storage.*—A license is required, and a special corporation license for quantities exceeding 100 barrels, but with regard to the actual quantities permitted, the terms of the ordinance are somewhat conflicting. In one place, it limits the amount to 1 barrel, in metallic packages,. in buildings other than dwelling-houses, but in another, it states that oil for illuminating purposes may be kept on sale in stores, dwelling-houses, or other building (apparently in unlimited quantities). Spirit is limited to 15 gallons in one building. Refineries must be at least 50 feet from other buildings, or 100 feet, if the refineries are frame buildings. *Test.*—120° flash.

MASSACHUSETTS.—*Storage.*—Petroleum, in unlimited quantity, may be stored without license, in detached "specially adapted" buildings, surrounded by an embankment to prevent outflow, and at a distance of 50 feet from every other building (or screened by a wall 10 feet high and 12 inches thick). In all other cases, a license is necessary, the terms of which are at the discretion of the local authority. *Inspection.*—The corporation, or other local authority, must appoint inspectors annually. No oil may be kept or sold without having been inspected, and all oil failing to pass the standard test is considered as naphtha, the sale of which, under any assumed designation, is prohibited. Any inspector guilty of fraud, deceit, or culpable negligence in the discharge of his duties, is liable to fine or imprisonment, as well as to be mulcted in damages for injury or loss sustained by any person through the explosion or ignition of any oil falsely certified by him (*Supplement to General Statutes*, vol. i., chapters clii. and cccxlv.). *Test.*—100° flash; Tagliabue open cup.

City of Boston.—License is required, the conditions being left to the corporation, except that a license may not be granted for storage at wharves or on inhabited premises, or for keeping any spirit elsewhere than in cellars, unless securely packed in metallic vessels. A license shall be held to be revoked, if any of the conditions under which it is issued are not observed, and the corporation may annul a license at any time.

MICHIGAN.—*Storage.*—No State law. *Test* (1893).—120° flash; Foster cup; or 148° fire.

MINNESOTA.—*Storage.*—There are no State regulations. *Test.*—110° flash; Minnesota cup. *Inspection.*—A supervisor of inspectors is appointed by the State, and he is required to confirm the nomination of inspectors made by the local authorities.

Town of Duluth.—The limit of storage is 20 barrels (5 barrels in the business districts), except in such cases and under such conditions as shall have been approved by the board of fire engineers.

City of Minneapolis and other cities.—The storage of petroleum is regulated by the fire marshal.

MISSISSIPPI.—No State law exists relating to petroleum products.

MISSOURI.—*Storage.*—No State regulations. *Inspection* (Law of 11th June, 1879).—All oil "burning" below 150° F. must be branded:—"Rejected for illuminating purposes;" above 150° "approved standard oil;" with inspector's name, date, place of examination, and the igniting point. Oils igniting at ordinary temperatures must be marked with specific gravity and "highly inflammable." No oil or fluid igniting below 150° may be sold for illuminating except with a view to its use as vapour or gas. If oil in bulk is tested, the sample must be taken from the top of the storage tank, and the inspector or deputy must see the oil subsequently placed in the packages for sale, and brand the same. Selling uninspected or low-test oil, or fraudulently altering inspectors' brands, involves penalty. Inspectors are empowered to examine suspected oils, and must prosecute offenders. Delinquent inspectors can be dismissed. *Test.*—150° fire; Tagliabue or other approved instrument. *Directions for Testing.*—The oil cup is to be filled up to one-third of an inch from the brim with oil at 60° F. and the oil must be entirely surrounded by the water in the water bath. The application of heat must be regulated so as to produce a rise in temperature of 2° per minute, between 60° and 118°. At this latter point, the lamp must be withdrawn and the oil allowed to reach 120° by the heat of the water bath, before applying the lighted oak "splint," or small gas flame, to test for a flash. If no flash is produced, the heating is continued and the light applied at every 4° (3° rise produced by the lamp heat and 1° by the heat of the water bath) until flashing occurs, and beyond that point, at every 4° rise, until ignition takes place.

City of Jackson.—The only conditions appear to be that buildings used for the storage of mineral oils must be fire proof and isolated.

MONTANA.—Fire wardens appointed under the State authority are empowered, among their other duties, to examine any building in cities or towns, and direct the removal of any inflammable material therein found, and test any oil they may find therein. *Test.*—110° flash.

NEBRASKA.—*Storage.*—No regulations. *Test.*—Over 100° flash; Foster cup. *Application of test* (*Act of 27th February*, 1875).—Half a pint of oil is to be placed in a small vessel with a surface not exceeding 4 square inches, and gradually heated at a rate of not less than 2° per minute, as indicated by a thermometer immersed in the oil, to a temperature at which the oil will emit a "gas or vapour" that will ignite when the flame of a match or taper is brought in contact with it; the application of the light being carefully and frequently made so as to indicate the exact temperature at which ignition occurs. No untested or low-test oil may be sold for illuminating purposes under penalty of fine and imprisonment, and liability for damages in case of injury resulting from any infraction of this Act. Death resulting from infraction of Act is considered to be manslaughter on the part of the offender. Contracts made in contravention of Act are invalid, and buyer may return the oil to vendor, and recover cost, freight, charges, and damages. No provision is made for inspection.

NEVADA.—No State law.

NEW HAMPSHIRE.—*Storage.*—The regulations are practically identical with those of Massachusetts (*q.v.*). *Test.*—100° flash, or 120° fire; Tagliabue or other approved instrument. The sale of illuminating oil or compound, made from coal or petroleum, which will flash below 100°, or ignite below 110°, is prohibited. Sellers of oils below standard test, are liable for any damage resulting from the ignition or explosion thereof.

NEW JERSEY.—*Storage.*—No regulations. *Test.*—100° flash; 115° fire.

City of Hoboken—*Storage.*—For quantities in excess of 100 gallons, a license is required, and this license defines the mode of construction of the place of storage and the amount to be kept. A safety zone of 200 feet from every dwelling-house and from manufacturing premises (except with the occupier's consent) is prescribed.

City of Newark.—*Storage.*—There are no regulations, but the distillation or refining of petroleum within the city limits, is prohibited. *Test.*—110° fire.

NEW MEXICO.—No oil of a fire test below 150° F. may be offered for sale, retail, for illuminating purposes.

NEW YORK (STATE).—*Storage* (*Revised Statutes, New York*—Banke's sixth edition, vol. ii., p. 254, title vi., chap. xvii., part i.).—No license is required. The limits of quantity are—

		Mineral Oil.	Mineral Spirit.
In any part of a dwelling, . . .		5 barrels.	3 barrels.
In buildings other than dwellings—			
Above cellar or basement, .	In barrels or retailing tanks,	10 ,,	10 ,,
,,	In hermetically closed metallic packages,	100 ,,	10 ,,
In cellars, &c., 2 feet below ground level, ...		150 ,,	
In detached masonry or iron warehouses specially constructed, with floor 2 feet below ground level, 50 feet from other buildings, or separated by intervening wall 10 feet high and 16 inches thick, or (*in case of refineries*) in wrought-iron tanks outside any building, or buried in the ground, so that the top is at least 2 feet below the surface, and covered with a minimum thickness of 1 foot of earth, ...		Unlimited.	

The Act is not to apply to any place where oil springs may be discovered and worked. *Test.*—110° fire; Tagliabue, or other approved instrument.

City of Auburn.—No law relating to the storage of petroleum products.

City of Brooklyn (1881).—*Storage.*—A license from the Commissioner of the Fire Department is required. In any building, occupied wholly or in part as a dwelling, only one barrel may be kept. The quantity, under other conditions, would (apparently) be prescribed by the license. *Test.*—110° fire; Tagliabue, or other approved instrument.

City of New York (1882).—*Storage.*—The State law (*q.v.*) is specially applicable to the City of New York. An annual license is required, and a special permit for warehouses. The limits of quantity are—

	Oil.
Inside any part of a dwelling-house, ...	1 barrel.
Above the first storey of any other building, . .	5 barrels.
Above the cellar or basement, ...	10 ,, or 50 ,, in the daytime.

For larger quantities, the regulations are the same as those in the State of New York, but it is not clear whether any spirit may be kept. In one place, the storage of spirit is prohibited, except in detached warehouses, but it appears to be sanctioned in another paragraph, under the same conditions as refined oils. Elsewhere, however, the keeping of spirit for illuminating or heating purposes is forbidden. *Test.*—100° a [illegible]iott cup.

[illegible]*ions governing vessels lying in Petroleum Docks in the Counties of New* [illegible]*rk, King's, and Queen's* (*Law of* 19*th May*, 1879, *chap.* 324).—

Captain must report arrival of vessel. No fires or lights are allowed on board without written permission of the wharfinger, who will supply cooking conveniences. No fires, smoking, or lights of any kind allowed on boats or vessels—except steam tugs and fire engines in the discharge of their duties—lying within 150 feet of any place where petroleum, or its products, is kept for export, or in quantities exceeding 10,000 gallons, unless by permission, in writing, of the owner, lessee, or superintendent of such store, specifically stating the kind of light or fire, and the purpose and place for which it is required.

Port of New York Harbour Master's Regulations, 1st July, 1880.—These rules relate to the position of vessels lying at wharves, and, generally, to the control of vessels while in the port, without particular reference to petroleum ships. The heating of pitch, tar, or other combustibles on board vessels lying at wharves, &c., in New York or Brooklyn, is prohibited.

City of Poughkeepsie (1874).—*Storage.*—No license is needed. 10 barrels of oil may be kept in any store or building within 300 feet of any dwelling-house, and an unlimited quantity beyond this distance.

City of Syracuse.—*Storage.*—The regulations are the same as for the State of New York (*q.v.*). *Test*—110° fire; Tagliabue open cup.

NORTH CAROLINA.—No State law referring to petroleum storage. *Test.*—100° flash; Foster cup.

NORTH DAKOTA.—*Test.*—100° flash.

OHIO.—*Storage.*—No State law, but laws and regulations similar to those in force in Philadelphia (*q.v.*), prevail in all the chief cities. *Inspection* (*Law of* 15*th May,* 1878).—Manufacturers, retailers, and others, offering low-test or untested oils for sale for lighting purposes, except to municipal authorities for lighting street lamps, are liable to fines, and are further liable for any injuries caused by the ignition of such oils. A buyer, finding any oil to be below standard test, may return the same to the vendor, and recover cost, carriage, and damages. Inspectors or deputies must brand all vessels containing standard test oil:—"approved;" and low-test oil:—"rejected for illuminating purposes;" with date of inspection. Inspectors are sworn, must furnish bond for surety, must keep a record of all tests, open for inspection, and make an annual return to the Governor. Deputies must make a monthly return to the chief inspector. No inspector or deputy may trade directly or indirectly in any oil or product which he is appointed to inspect. Breach of this rule, or other dereliction of duty, involves fines and dismissal. Disputed tests must be submitted to the State chemist of the Agricultural College at Columbus, and his decision shall be final. Fraudulently altering inspector's brands, or refilling branded vessels with untested oil, is a misdemeanour. No empty branded casks or vessels may be sold without the marks being first obliterated. The adulteration of standard with low-test oils is prohibited, if they are thereby rendered dangerous. Gas or vapour from low-test oils may be used for illumination, provided the liquid is contained in underground reservoirs, outside the building lighted by such gas. *Testing.*—The oil cup is a metal or glass cylinder 2½ inches diameter by 4 inches deep inside, and filled to within ¼ inch of the brim. The water bath is ¾ inch wider than the oil cup, and the latter projects ¼ inch above the edge of the bath, leaving a clear space of 1 inch underneath. The bath being filled with cold water, heat is applied by a flame regulated to produce a rise of not less than 2° per minute (maximum 4°). The bulb of the thermometer is placed ¼ inch below the surface of the oil. At 98°, the lamp is removed, and at 100°, the test is applied. The test-flame consists of a lighted wood "taper," $\frac{1}{16}$ of an inch in thickness at the tip, and this is drawn across the surface of the oil so that only the flame touches. If no flash is observed, the test is repeated every 5° (3° with the lamp under the water bath, and 2° without the lamp), the lighted taper being applied at every second degree obtained by the heat of the lamp, and if a flash occurs, the lamp should be removed, the oil stirred, and the light again applied. The standard test is 120° flash, and the inspector may use a Foster cup, in place of the apparatus described above, if he considers that greater uniformity of results will thus be ensured.

CITY OF CINCINNATI.—*Storage.*—Within certain "fire limits," the quantity allowed to be kept in any one building, is restricted to 10 barrels, unless specially erected stores at least 60 feet from any other building are employed, in which case there does not appear to be any limit as to quantity. The smaller dealers are nominally restricted to 5 barrels.

OREGON.—No state law relating to petroleum products.

CITY OF PORTLAND.—*Storage.*—A license is requisite for the storage of over 1,000 gallons of petroleum "that will emit an inflammable vapour" (no mention being made of temperature or testing instrument). This regulation does not seem to apply outside a certain specified area. The construction of stores for larger quantities, appears to be regulated by the license.

PENNSYLVANIA.—*Pennsylvania State Laws for Petroleum* (*P. L.* 189, *May* 15, 1874):—

1. No refined petroleum, kerosene, naphtha, benzol, gasoline, or any fluid, be they designated by whatsoever name, the fire test of which shall be less than 110 degrees Fahrenheit, shall be sold or offered for sale as an illuminator for consumption within the limits of the Commonwealth of Pennsylvania.

2. Said fire test shall be determined by an inspector appointed under the provisions of this Act, who shall use Tagliabue's or such other well-defined instrument as may be used by the inspectors of export oil, according to the following formula:—Heat with alcohol, small flame; when thermometer indicates ninety degrees, remove lamp; at ninety-five try for a flash, with small bead of fire on end of string, held within a quarter of an inch of surface of oil; replace lamp, and work oil up gradually from this point until the burning point is reached, removing lamp every four degrees, and allowing oil to run up three degrees before replacing lamp, flashing oil each time, just before lamp is replaced, until result is attained.

3. The said inspector shall be appointed by the courts of common pleas, one in each county in the commonwealth, wherein said burning oil or fluids, as before mentioned, are manufactured: *Provided* that, in any county where there shall be more than one Court of Common Pleas, the said appointments shall be made by Court No. 1 in said counties, and in any county wherein is situated a city of more than three hundred thousand inhabitants, in such case, in lieu of Court No. 1, the appointment of inspector shall be made by the mayor of said city.

4. The said inspectors shall hold their office for the term of three years, unless sooner removed by the appointing power for incompetency, or found guilty under the provisions of this Act; vacancies in said office to be filled by the authority in which the appointing power is vested by this section. The said inspectors shall be authorised to appoint such clerks or deputies as they may find requisite for the carrying out of the duties specified under this Act; the said clerks and deputies shall be paid out of the fees of the office by the inspector of the county wherein the service is performed; all clerks and deputies are held answerable by this Act, and subject to the same penalties for violating any of its provisions as are provided in this Act for the punishment of the appointed inspectors. Each inspector, deputy, or clerk, after receiving his appointment, and prior to entering upon the duties of the office for which he is appointed, shall file in the office of the prothonotary of the Court of Common Pleas, an oath or affirmation that he will well and truly perform the duties of his office, and carry out the provisions of this Act, and said inspectors shall also file a bond, with one or more approved securities, in style similar to that of the sheriff of the county, in the penal sum of ten thousand dollars, for the faithful performance of the duties of said inspector's office, as provided in this Act. The said inspector is hereby empowered to receive and collect from the manufacturer or owner, the sum of twenty cents per package for each package inspected in any lot under ten; ten cents per package for each package inspected in any lot not more than fifty; seven cents per package for each package inspected in any lot or all lots over fifty; and one dollar for each car of bulk refined oil; and in case any person shall call upon said inspector to inspect one package of refined oil, he shall charge said person for each inspection fifty cents. The said inspector shall provide, at his own cost, stencils for the purpose of branding packages, to read thus—"State of Pennsylvania, fire test one hundred and ten degrees," with name of inspector: *Provided*, when oil so inspected shall stand higher test, the inspector shall designate such actual test by his brand.

5. The said inspector, or his clerks or deputies, shall, and are hereby empowered to, enter any place or building where oil or fluids, as before designated in this Act, are manufactured, kept in store for sale or consumption, in this commonwealth, and in such counties where oil is sold and not manufactured, for which no inspector has been appointed, or in any other place within the limits of this State, wherein he has reason for believing that oil is being kept or sold contrary to the provisions of this Act, or for the purpose of carrying out the true intent and meaning of this Act, any inspector shall have the privilege to reinspect, and is hereby empowered to inspect any oil, as hereinbefore designated in section first, which he may by any reason believe to be under fire test, and if so found by him to be under fire test, and falsely branded, he shall prosecute, or cause to be prosecuted, the offender, as herein authorised in section four of this Act; no charge shall be made for reinspection.

6. Any person violating any of the provisions of this Act shall, upon conviction thereof, be deemed guilty of a misdemeanour, and shall be subject to a fine of not less than two hundred and fifty ($250) dollars, nor more than five hundred ($500) dollars, or imprisonment not less than one year, or both, at the discretion of the Court, one-half of said fine to go to the prosecutor, and one-half to the school fund in the district where such misdemeanour may have been committed. Also, if any person shall sustain damage to his property or injury to his person, by reason of a violation of any of the provisions of this Act by another person, the person guilty of said violation shall be liable to the person injured, for all damages sustained thereby.

7. All the oils or fluids, subject to inspection under this Act, that may be found in the hands of those who sell in less quantities than one barrel, with a fraudulent brand or mark of inspection, or found to have been adulterated, or not coming up to the fire test, as the mark of inspection would indicate, shall be subject to seizure by the said inspector, and the same shall, after ten days' public notice, be sold solely for redistillation, the proceeds of such sale, after deducting the necessary expenses of sale and seizure, shall one-half be given to the public school fund wherever the seizure was made, and one-half to the informer.

8. Any inspector or deputy appointed under this Act, who shall violate any of

its provisions by neglecting to inspect upon request, or shall falsely brand any oil or fluid, shall be deemed guilty of a misdemeanour, and, upon conviction thereof, shall be fined not less than two hundred and fifty ($250) dollars, nor more than one thousand ($1,000) dollars, and be subject to imprisonment for not less than three months or more than one year, or both, subject to the discretion of the Court, one-half of the fine to go to the informer, and one-half to the school fund of the district wherein the offence was committed.

9. The packages containing oil manufactured for export shall be branded with a stencil by the manufacturer, with the words "for export," all benzine, naphtha, or any hydrocarbons, created in the manufacture of refined oil from crude petroleum, or otherwise manufactured, shall be inspected and branded "benzine," and shall not be kept for sale or used in any way for giving light to be burned in lamps, and this Act shall not be construed to prohibit their use in making gas to be conveyed through pipes to burners, similar to gas in city gas works, to be used for the same purpose, and, further, the penalties for violating this section shall be the same as applied to the use of refined oil below legal test.

10. Nothing contained in this Act shall be construed or held to apply in any manner, to any kind of oil or fluid manufactured for export from this State, or in transit from one State to another through the limits of this commonwealth.

11. Any person or persons who shall sell or cause to be sold, any barrel or package, or who shall refill the same without first removing the brand of the inspector, shall be liable to a fine of three hundred dollars for every barrel or package sold or delivered or refilled, said fines shall be recoverable as other fines of like character are recoverable by law, and one-half shall go to the informer, and one-half to the school fund of the district in which the offence was committed.

CITY OF PHILADELPHIA.—*Storage.*—An annual license from the corporation is necessary. Within certain limits in the city, 25 barrels of oil, or 1 barrel of mineral spirit, may be kept in cellars, or on premises properly excavated or embanked to prevent outflow. Beyond the aforesaid limits, oil may be stored up to any amount in buildings, tanks, or excavations, approved by the fire marshal, and situated at least 100 feet from any dwelling. This does not apply to any dwelling in respect to which the consent of the occupier has been obtained. Oil in bond or for export, beyond the confines of Pennsylvania, is not subject to the Act (1865). *Test.*—110° fire; Tagliabue cup.

RHODE ISLAND.—*Storage.*—No license is necessary. Limits of quantity :—

	Oil.
In any store or warehouse, ...	3 barrels.
In cellars 4 feet below ground level, and not below a dwelling, ...	10 ,,
In warehouses of masonry or iron, specially constructed,	100 ,,
Ditto, 50 feet from buildings and wharves (or if less than 50 feet, separated by masonry wall 10 feet high and 16 inches thick), and constructed to prevent outflow, ...	Unlimited.

Apparently no mineral spirit may be kept, at any rate for illuminating purposes. *Test.*—110° fire. *Inspection.*—The sale of oil flashing below 110°, and the transfer from the original packages, of any oil or spirit brought into the State, until it has been inspected, are prohibited under penalty. Inspectors must brand every cask with the flashing point of the oil, in a legible manner. The obliteration or alteration of inspectors' brand marks, or putting untested oil into packages already bearing such brands, is punishable by fine or imprisonment (*General*

Statutes of Rhode Island and Providence Plantations, Title xvi., Chap. 112).

SOUTH CAROLINA.—No State law exists relating to petroleum products.

CITY OF CHARLESTON.—*Storage.*—No license is required. The maximum amount of any petroleum products or other inflammable oils, which may be kept in any cellar, store, or building, or any one block of premises in the principal portion of the city (*i.e.*, south of Line Street) is 50 gallons, and this must be kept in vessels of tin or other metal. Oils are only subject to these regulations after a lapse of twenty-four hours from the time of their arrival in the city.

SOUTH DAKOTA.—*Test.*—Over 110° flash. Instrument, and mode of testing are prescribed by State Board of Health. Foster cup used.

CITY OF YANKTON.—*Storage.*—Permission must be obtained from the City Council for the storage of 5 barrels (the limit of quantity) within the fire limits of the city.

TENNESSEE.—*Storage.*—No State law. *Inspection* (*State Law*, 10*th March*, 1877).—An inspector of illuminating oils is to be appointed by the Governor, for each city and county having a population of 1,000 and over, to inspect and test all illuminating oils made or offered for sale in the State, and to brand all vessels, either as:—"Approved standard oil" (stating the flashing point), if they pass the test; or as—"Rejected," if they fail to do so; and in the latter case, if they are inflammable at ordinary temperatures, with the specific gravity as well. An inspector or his assistant may go to any county not provided with an inspector, if he hears that low-test oil is being sold for illuminating purposes without being branded, and may test the same. Furthermore, he may inspect oils in transit from other states to counties having no inspector, and if the same fail to pass the test, may send them back to the shipper, but if the said oils are plainly marked by the manufacturer or shipper as not intended for illuminating purposes, they may be allowed to go forward to their destination. The inspector's fees on oils in transit, are collected from the carrier or forwarding agent, who has a lien on the goods until repaid by the shipper. Refusal on the part of a carrier to pay the fees, or obstruction, by any one, of the inspector in the discharge of his duties, is punishable by fines, as is also the selling of low-test or untested oil for lighting purposes, or fraudulent alteration of brands. *Test.*—120° flash; open cup. The "standard" instrument must be used. The water bath must contain sufficient water to rise two-thirds up the side of the oil cup. The latter must be filled up to $\frac{1}{8}$ of an inch from the top, with the oil to be tested, and be provided with a thermometer, the bulb of which is just covered by the oil. The oil is first tested, before applying heat, by bringing a lighted match in contact with its surface. If no flash occurs, it is then slowly heated by means of an alcohol lamp at the rate of 1° to 2° per minute, a lighted match being drawn across the surface at a distance of $\frac{3}{8}$ of an inch at each degree rise, until a flash occurs.

CITY OF MEMPHIS.—*Storage.*—In certain parts of the city, not more than 5 barrels (and even then only in tin cases) may be stored on the same premises. In the remaining districts there does not seem to be any limit as to quantity, provided that storage takes place in fire-proof buildings approved by the chief of the fire brigade.

TEXAS.—No state law exists relating to petroleum products.

CITY OF GALVESTON.—*Storage.*—Not more than 40 gallons may be stored in a dwelling, or above the first floor of any building. Beyond this quantity of "camphene or dangerous inflammable fluid, such as kerosene, naphtha, or any inflammable oil of any kind or nature whatever," a license from the mayor is required, but this license may only be granted on certificate from the chief engineer of the fire brigade that the building is suitably arranged for the prevention of outflow, and that the adjoining premises would not be endangered in case of fire. It is forbidden to grant a license for storage in any dwelling, or for storage above the first floor in any building, or for storage in "any street, alley, or wharf." The police, and the chief engineer of the fire brigade, or person authorised by the mayor, may enter and inspect stores, and take samples.

VERMONT.—*Storage.*—The regulations in this State are practically identical with those of Massachusetts (*q.v.*). *Test.*—110° fire; Tagliabue cup.

VIRGINIA.—No State regulations relating to petroleum products.

CITY OF RICHMOND.—*Storage.*—No law. *Test.*—110° fire test; Tagliabue cup.

WASHINGTON.—No State law on petroleum products.

WEST VIRGINIA.—No State regulations applying to petroleum.

WISCONSIN.—*Storage.*—No State law. *Inspection.*—The appointment of a State supervisor of inspectors is compulsory. The appointment of inspectors to test oils, is vested in the supervisor—*i.e.*, this official confirms the nominations made by local authorities. *Test.*—120° flash; Wisconsin cup.

CITY OF MADISON.—*Storage.*—The limit of quantity is 6 barrels, but no license is required.

CITY OF MILWAUKEE.—*Storage.*—Mineral spirit may be kept only in approved fire-proof buildings, exclusively appropriated to the storage of such articles in such quantities as may be assigned in the license. Refined petroleum of over 110° test, may be stored to the extent of 6 barrels by day, or 1 barrel by night, without license. Above these limits, the place of storage must be a fire-proof building, sufficiently removed and detached from other buildings, approved by the chief engineer of the fire department, and duly licensed. *Test.*—110° flash.

WYOMING.—No State law in reference to test. Fire Wardens, appointed under the State authority, are empowered, among their other duties, to examine any building in cities or towns, and direct the removal of any inflammable material therein found, and test any oils they may find therein.

VICTORIA—*See* AUSTRALIAN COLONIES.

WEST AUSTRALIA—*See* AUSTRALIAN COLONIES.

ZANZIBAR.

By a decree of the Sultan, Sayyid Ali Byn Said, dated 27th April, 1892, it was ordained that, all petroleum, kerosene, and other "explosive" oils for lighting purposes (without reference to flashing point) should be stored, immediately on arrival, in a specially appointed warehouse. The limit of quantity to be stored in a house, or on other premises, is 10 cases, but responsible merchants are allowed to keep up to 50 cases in their own godowns.

Concluding Remarks.—From the particulars which have been given in this section and a previous one, it will be evident that there is a regrettable absence of uniformity in the methods of testing adopted, not only in different countries, but also in the various States of the American Union. The existence of considerable diversity in regard to the test standard to be adopted with any one system of testing, is also exhibited in the laws which have been framed in the United States. The latter condition, no doubt, arises from the fact that, until lately, no systematic attempts were made to determine the relation between the flashing point of an oil and its safe or dangerous character in ordinary use. Moreover, when petroleum was first introduced, it was often carelessly or improperly handled, and the accidents which occurred led to an exaggerated estimate being formed of the risk involved in the use of the oil as an illuminant, with the result that legislative restrictions of a needlessly stringent description have been placed upon the trade. It may be added that in certain of the States, the oil in general use, prior to the adoption of any restriction as to "test," happened to be of high flashing point, and in these cases, the standard, or limit of test, was simply based upon the character of the oil commonly employed in the locality.

APPENDIX A.

STATISTICS.

THE United States and Russia occupy predominant positions in the petroleum industry, and full statistical data in respect to these countries will be found in the following pages. Particulars of a less exact character are also given in relation to Canada, Galicia, Italy, and Japan; in several countries, however—*e.g.*, Peru, Java and Sumatra, Upper and Lower Burma—there are no arrangements for the collection of statistics of production, and for this reason, no attempt has been made by the author to prepare a table giving the world's production.

The following statistical information may be supplemented as regards individual fields or deposits of minor importance, and in respect of such particulars as are of historical interest or are unsuited for arrangement in tabular form, by reference to the earlier sections of this work.

PRODUCTION OF CRUDE PETROLEUM IN THE UNITED STATES FROM 1859 TO 1894 (in Barrels of 42 American Gallons).

Year.	Pennsylvania and New York.	Ohio.	West Virginia.	Colorado.	California.	Indiana.	Kentucky and Tennessee.	Illinois.	Kansas.	Texas.	Missouri.	Indian Territory.	Total. United States.
1859	2,000	..	..	..	..	..	..	..	..	..	..	..	2,000
1860	500,000	..	..	..	..	..	..	..	..	..	..	..	500,000
1861	2,113,609	..	..	..	..	..	..	..	..	..	..	..	2,113,609
1862	3,056,690	..	..	..	..	..	..	..	..	..	..	..	*a*3,056,690
1863	2,611,309	..	..	..	..	..	..	..	..	..	..	..	2,611,309
1864	2,116,109	..	..	..	..	..	..	..	..	..	..	..	2,116,109
1865	2,497,700	..	..	..	..	..	..	..	..	..	..	..	2,497,700
1866	3,597,700	..	..	..	..	..	..	..	..	..	..	..	3,597,700
1867	3,347,300	..	..	..	..	..	..	..	..	..	..	..	3,347,300
1868	3,646,117	..	..	..	..	..	..	..	..	..	..	..	3,646,117
1869	4,215,000	..	..	..	..	..	..	..	..	..	..	..	4,215,000
1870	5,260,745	..	..	..	..	..	..	..	..	..	..	..	5,260,745
1871	5,205,234	..	..	..	..	..	..	..	..	..	..	..	5,205,234
1872	6,293,194	..	..	..	..	..	..	..	..	..	..	..	6,293,194
1873	9,893,786	..	..	..	..	..	..	..	..	..	..	..	9,893,786
1874	10,926,945	..	..	..	..	..	..	..	..	..	..	..	10,926,945
1875	8,787,514	*b*200,000	*b*3,000,000	..	*b*175,000	..	..	..	..	..	..	..	*b*12,162,514
1876	8,968,906	31,763	120,000	..	12,000	..	..	..	..	..	..	..	9,132,669
1877	13,135,475	29,888	172,000	..	13,000	..	..	..	..	..	..	.	13,350,363
1878	15,163,462	38,179	180,000	..	15,227	..	..	..	..	..	..	..	15,396,868
1879	19,685,176	29,112	180,000	..	19,858	..	..	..	..	..	..	..	19,914,146
1880	26,027,631	38,940	179,000	..	40,552	..	..	..	..	..	..	..	26,286,123
1881	27,376,509	33,867	151,000	..	99,862	..	..	..	..	..	..	.	27,661,238
1882	30,053,500	39,761	128,000	..	128,636	..	*c*160,933	..	..	..	..	..	30,510,830
1883	23,128,389	47,632	126,000	..	142,857	..	4,755	..	..	..	..	..	23,449,633
1884	23,772,209	90,081	90,000	..	262,000	..	4,148	..	..	..	..	..	24,218,438
1885	20,776,041	650,000	91,000	..	325,000	..	5,164	..	..	..	..	..	21,847,205
1886	25,798,000	1,782,970	102,000	..	377,145	..	4,726	..	..	..	..	..	28,064,841
1887	22,356,193	5,018,015	145,000	76,295	678,572	..	4,791	..	..	..	..	..	28,278,866
1888	16,488,668	10,010,868	119,448	297,612	690,333	..	5,096	..	..	..	..	..	27,612,025
1889	21,487,435	12,471,466	544,113	316,476	303,220	33,375	5,400	1,460	500	48	20	..	35,163,513
1890	28,458,208	16,124,656	492,578	368,842	307,360	63,496	6,000	..	1,200	54	278	..	45,822,672
1891	33,009,236	17,740,301	2,406,218	665,482	323,600	136,634	9,000	..	1,400	54	25	30	54,291,980
1892	28,422,377	16,362,921	3,810,086	824,000	385,049	698,068	6,500	..	..	45	10	80	50,509,136
1893	20,314,513	16,249,769	8,445,412	594,390	470,179	2,335,293	3,000	..	..	50	50	10	48,412,666
1894	18,960,300	*d*18,039,372	8,553,046	600,000	427,050	3,719,601	..	..	100,000	..	..	..	50,399,369
Total.	497,453,180	115,029,561	29,034,901	3,743,097	5,196,500	6,986,467	219,513	1,460	103,100	251	383	120	657,768,533

Note.—In the United States, the barrel of crude oil is reckoned as 42 American gallons, and the barrel of refined oil, or other product, as 50 American gallons. (100 American gallons = 83·3 Imperial gallons.)

a In addition to this amount, it is estimated that for want of a market, some 10,000,000 barrels ran to waste, in and prior to 1862, from the Pennsylvanian fields; also a large amount from West Virginia and Tennessee.

b Including all production prior to 1876 in Ohio, West Virginia, and California.

c This includes all the petroleum produced in Kentucky and Tennessee prior to 1883.

d This includes 3,183,370 barrels of "Pennsylvania"—*i.e.*, Appalachian—oil.

Quantity of Crude Petroleum Produced in, and the Quantities and Values of Petroleum Products Exported from, the United States during each of the Calendar Years from 1871 to 1893, inclusive.

Year ending Dec. 31.	Production.		Exports.											
	Barrels (of 42 gallons).	Gallons.	Mineral, Crude (including all natural oils without regard to specific gravity).		Mineral, Refined or Manufactured.						Residuum (tar, pitch, and all other from which the light oils have been distilled).		Total.	
					Naphthas, Benzine, Gasoline, &c.		Illuminating.		Lubricating (heavy paraffin, &c.).					
			Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.
1871	5,205,234	218,619,828	11,278,589	2,171,706	8,396,905	895,910	132,178,843	33,493,351	240,228	92,408	101,052	10,450	152,195,617	36,663,825
1872	6,293,194	264,314,148	16,363,975	2,761,094	8,688,257	1,307,058	118,259,832	29,456,453	438,425	180,462	568,218	56,618	144,318,707	33,761,685
1873	9,893,786	415,539,012	19,643,740	2,665,171	10,250,497	1,266,962	207,595,988	41,357,686	1,502,503	517,466	1,377,180	117,595	240,369,908	45,924,880
1874	10,926,945	458,931,690	14,430,851	1,428,494	10,616,644	997,355	206,562,977	30,168,747	993,068	269,886	2,504,628	177,794	235,108,168	33,042,276
1875	12,162,514	*b*510,825,588	16,536,800	1,738,589	14,048,726	1,392,192	203,678,748	28,168,572	938,052	265,837	2,323,986	169,671	237,526,312	31,734,861
1876	9,132,669	383,572,098	25,343,271	3,343,763	13,252,751	1,502,498	220,831,608	44,089,066	1,157,929	370,431	2,863,896	239,461	263,449,455	49,545,219
1877	13,350,363	560,715,246	28,773,233	3,267,309	19,565,909	1,938,672	307,373,842	51,366,205	1,914,129	577,610	4,256,112	390,077	361,883,225	57,539,873
1878	15,396,868	646,668,456	24,049,604	2,169,790	13,431,782	1,077,402	306,212,506	36,855,798	2,525,545	698,182	3,126,816	220,835	349,346,253	41,022,007
1879	19,914,146	836,394,132	28,601,650	2,069,458	19,524,582	1,367,996	365,597,467	32,811,755	3,168,561	713,208	4,827,522	273,050	421,719,782	37,235,467
1880	26,286,123	1,104,017,166	36,748,116	2,772,400	15,115,131	1,344,529	286,131,557	29,047,908	5,607,009	1,141,825	3,177,630	198,983	346,779,443	34,505,645
1881	27,661,238	1,161,771,996	40,430,108	3,089,297	20,655,116	1,981,197	444,666,615	42,122,683	5,053,862	1,165,605	3,756,018	197,321	514,561,719	48,556,103
1882	30,510,830	1,281,454,860	45,011,154	3,373,302	16,969,839	1,304,041	428,424,581	37,635,981	8,821,536	2,034,487	4,265,352	275,263	503,492,462	44,623,074
1883	23,449,633	984,884,586	59,018,537	4,439,097	17,365,314	1,195,035	440,150,660	39,470,352	10,108,394	2,193,245	6,502,524	465,350	533,145,429	47,763,079
1884	24,218,438	1,017,174,396	79,679,395	6,102,810	13,676,421	1,132,528	433,851,275	39,450,794	11,985,219	2,443,385	5,303,298	327,599	544,495,608	49,457,116
1885	21,847,205	917,582,610	81,435,609	6,040,685	14,739,469	1,160,999	445,880,518	39,476,082	12,978,955	2,659,210	5,713,908	334,767	560,784,459	49,671,743
1886	28,064,841	1,178,723,322	76,346,480	5,068,409	14,474,951	1,264,736	485,120,680	39,012,922	13,948,367	2,689,464	1,993,824	109,673	591,884,302	48,145,204
1887	28,278,866	1,187,712,372	80,650,286	5,141,833	12,382,213	1,049,043	485,242,107	37,007,336	20,582,613	3,559,280	2,989,098	141,350	601,846,317	46,898,842
1888	27,612,025	1,159,705,050	77,549,452	5,454,705	13,481,706	1,083,429	455,045,784	37,236,111	24,510,437	4,215,449	1,870,596	116,009	572,457,975	48,105,703
1889	35,163,513	1,476,867,546	85,189,658	6,134,002	13,984,407	1,208,116	551,769,666	41,215,192	27,903,267	4,638,724	1,858,458	97,265	680,705,456	53,293,299
1890	45,822,672	1,924,552,224	96,572,625	6,535,499	12,462,636	1,050,613	550,873,438	39,826,086	32,090,537	4,766,850	1,830,612	91,905	693,829,848	52,270,953
1891	54,291,980	2,280,263,160	96,722,807	5,365,579	11,424,993	868,137	531,445,099	34,879,759	33,310,264	4,999,978	1,002,414	61,382	673,905,577	46,174,835
1892	50,509,136	2,121,383,712	104,397,107	4,696,191	16,393,284	1,037,558	589,418,185	31,826,545	34,026,855	5,130,643	403,032	38,220	744,638,463	42,729,157
1893	48,412,666	2,033,331,972	111,703,508	4,587,391	17,304,005	1,074,710	642,239,816	31,719,404	32,432,857	4,738,892	541,044	41,661	804,221,230	42,142,058

Note.—In the foregoing table, the gallons are American gallons (100 American gallons = 83·3 Imperial gallons).
b Including all production prior to 1876 in Ohio, West Virginia, and California.

Production of Crude Petroleum in Pennsylvania and New York in 1893, by Districts.

In barrels of 42 American gallons.

Districts.	
Allegany, N.Y.,	733,709
Bradford, Pa,	3,502,136
Middle District,	1,249,067
Clarendon and Warren,	327,680
Tiona,	286,595
Tidioute and Titusville,	225,348
Grand Valley,	54,700
Second Sand,	245,205
Lower District,	5,396,969
Washington County,	2,077,564
Beaver County,	465,300
Greene County,	74,377
Allegheny County,	5,488,792
	20,227,442
Franklin District,	66,278
Smith's Ferry District,	20,793
Total,	20,314,513

Production of Petroleum in the Lima, Ohio, District from 1886 to 1893.

Years.	Barrels.	Years.	Barrels.
1886,	1,064,025	1890,	15,014,882
1887,	4,650,375	1891,	17,315,978
1888,	9,682,683	1892,	15,169,507
1889,	12,153,189	1893,	13,646,804

Total Amount and Value of Petroleum Produced in Ohio from 1889 to 1893.

Districts.	1889.			1890.		
	Total Production.	Total Value.	Price per Barrel.	Total Production.	Total Value.	Price per Barrel.
	Barrels.			Barrels.		
Lima,	12,153,189	$1,822,978	$0.15	15,014,882	$4,504,465	$0.30
Macksburg,	317,037	340,683	1.07½	1,108,334	1,127,730	1.01¾
Eastern Ohio,	....	....	....	....	....	....
Mecca-Belden,	1,240	10,334	8.33⅓	1,440	12,000	8.33⅓
	12,471,466	2,173,995	0.17⅜	16,124,656	5,644,195	0.35

Districts.	1891.			1892.		
	Total Production.	Total Value.	Price per Barrel.	Total Production.	Total Value.	Price per Barrel.
	Barrels.			Barrels.		
Lima,	17,315,978	$5,281,373	$0.30½	15,169,507	$5,555,832	0.36\frac{6}{10}$
Macksburg,	400,024	283,332	0.67	197,556	662,106	0.55$\frac{6}{10}$
Eastern Ohio,	22,859			992,746		
Mecca-Belden,	1,440	12,000	8.33⅓	3,112	21,101	6.78
	17,740,301	5,576,705	0.31$\frac{4}{10}$	16,362,921	6,239,030	0.38

TOTAL AMOUNT AND VALUE OF PETROLEUM PRODUCED IN OHIO—*Continued.*

Districts.	1893.		
	Total Production.	Total Value.	Price per Barrel.
	Barrels.		
Lima,	13,646,804	$6,448,115	$0.47¼
Macksburg, Eastern Ohio,	2,601,394	1,664,892	0.64
Mecca-Belden,	1,571	11,335	7.21½
	16,249,769	8,124,342	0.50

TOTAL AMOUNT AND VALUE OF PETROLEUM PRODUCED IN WEST VIRGINIA FROM 1889 TO 1893.

Districts.	1889.			1890.		
	Total Production.	Total Value.	Price per Barrel.	Total Production.	Total Value.	Price per Barrel.
	Barrels.			Barrels.		
Turkey Foot,	199,460	$243,192	$1.21⅞	..	..	..
Mount Morris,	174,758	194,949	1.11½	..	..	..
Volcano and Eureka,	165,735	211,526	1.27⅝	..	..	..
Burning Springs,	4,160	4,160	1.00	..	..	..
	544,113	653,827	1.20⅙	492,578	$501,198	$1.01¾

Districts.	1891.			1892.		
	Total Production.	Total Value.	Price per Barrel.	Total Production.	Total Value.	Price per Barrel.
	Barrels.			Barrels.		
Turkey Foot, Mount Morris, Volcano and Eureka,	2,404,218	$1,610,826	$0.67	3,807,068	$2,117,692	$0.55⅝
Burning Springs,	2,000	2,000	1.00	3,000	2,209	0.73 6/10
	2,406,218	1,612,826	0.67	3,810,086	2,119,901	0.55 6/10

Districts.	1893.		
	Total Production.	Total Value.	Price per Barrel.
	Barrels.		
Turkey Foot, Mount Morris, Eureka, &c.,	8,427,448	$5,393,567	$0.64
Volcano,	12,000	27,000	2.25
Burning Springs,	5,964	4,955	0.83
	8,445,412	5,425,522	0.64

STOCKS OF PENNSYLVANIA CRUDE PETROLEUM AT THE END OF EACH YEAR FROM 1871 TO 1894.

	Barrels of 42 American gallons.		Barrels of 42 American gallons.
1871	532,000	1883	35,745,632
1872	1,084,423	1884	37,366,126
1873	1,625,157	1885	34,428,841
1874	3,705,639	1886	34,156,605
1875	3,550,207	1887	28,006,211
1876	2,551,199	1888	18,995,814
1877	3,127,837	1889	11,562,593
1878	4,615,299	1890	9,998,600
1879	8,470,490	1891	15,354,233
1880	18,928,430	1892	17,395,389
1881	26,019,704	1893	12,111,183
1882	34,596,612	1894	6,336,777

LABOUR EMPLOYED IN THE REFINING, &C., OF PETROLEUM, EXCLUDING THAT EMPLOYED IN THE MERCANTILE BRANCHES AND IN TRANSPORT, &C.

Superintendents,	28	Machinists,	140
Foremen,	195	Compounders,	4
Salesmen,	23	Boxmakers,	79
Bookkeepers,	9	Filter-housemen,	17
Clerks,	436	Barrel-housemen,	35
Boys, office, &c.,	555	Pumpmen,	69
Stillmen,	481	Fillers,	16
Chief stillmen,	12	Inspectors,	21
Still cleaners,	102	Packers and shippers,	52
Treaters,	132	Tinsmiths,	422
Coopers,	1,907	Painters and gluers,	18
Pipe-fitters,	200	Lightermen,	25
Labourers,	3,703	Blacksmiths,	36
Engineers,	114	Masons,	39
Firemen,	440	Solderers,	38
Yardmen,	44	Cap solderers,	35
Mechanics,	271	Bricklayers,	11
Pressmen,	246	Car builders,	75
Boiler-makers,	302	Faucet makers,	28
Boilermen,	115	Lead burners,	3
Bone burners,	15	Candle makers,	9
Teamsters,	165	Unclassified,	1,516
Watchmen,	126		
Carpenters,	227	Total,	12,536

In addition, there are 19,832 men employed in the production of the crude oil, the total number engaged in the industry being, therefore, 32,368.

CLASSIFICATION OF LABOUR EMPLOYED IN THE PRODUCTION OF CRUDE PETROLEUM BY DISTRICTS, DURING THE YEAR ENDING DECEMBER 31, 1889.

(Compiled from the Eleventh Census Report of the United States.)

CLASS OF LABOUR.	BRADFORD—ALLEGANY DISTRICT.		FOREST COUNTY DISTRICT.		WARREN COUNTY DISTRICT.		BUTLER—CLARION—VENANGO DISTRICT.		ALLEGHENY COUNTY DISTRICT.	
	Number of each Class.	Range of Wages.	Number of each Class.	Range of Wages.	Number of each Class.	Range of Wages.	Number of each Class.	Range of Wages.	Number of each Class.	Range of Wages.
Foremen, . .	207	$100 to $133 p. month.	9	$50 to $100 p. month.	62	$40 to $100 p. month.	134	$20 to $100 p. month.	17	$45 to $100 p. month.
Pumpers or engineers, .	2,209	$5 to $85 per month.	57	$20 to $60 p. month.	442	$10 to $75 p. month.	2,538	$30 to $85 p. month.	144	$20 to $65 p. month.
Carpenters, . .	687	$2 to 3·50 per day.	10	$2 to $3·50 per day.	204	$2·50 to $3·25 p. day.	286	$1·25 to $3 per day.	10	$2·50 per day.
Rig builders, .	601	$50 to $190 per rig. $2·50 to $3 per day.	25	$62·75 to $125 p. rig.	302	$65 to $200 per rig.	1,234	$50 to $200 per rig.	46	$100 to $180 per rig.
Drillers, . .	1,061	40 cents to $1 p. ft. $3·50 to $4 per day.	50	40 to 60 cents per ft.	616	$40 to $90 p. month.	2,474	35 cents to $1 p. ft.	85	50 cents to $1·15 p. ft.
Tool dressers, .	22	$2·50 to $3 per day.	5	$3 to $3·50 per day.	34	$3 to 3·50 per day.	32	$2·50 to $3 per day.	..	....
Labourers, . .	882	$1·25 to $2·50 p. day.	22	$1·50 to $2·50 p. day.	444	$1·50 to $2 per day.	818	$1 to $2·50 per day.	6	$50 to $60 p. month.
Teamsters, . .	52	$50 to $125 p. month.	7	$5 per day.	86	$1·50 to $5 per day.	110	$2·50 to $5 per day.	..	....
Boys under 16 years,	8	$1 to $1·50 per day.	..	....	..	....	18	$10 to $20 p. month.	..	....
Well cleaners, .	334	$4 to $6·25 per day.	2	$5 per day.	84	$5 per day.	274	$2·50 to $5 per day.	2	$2·50 to $3·50 p. day.
Sundry mechanics,	69	$50 per month. $2·50 to $4 per day.	1	$60 per month.	20	$1·70 to $3·50 p. day.	74	$1·25 to $4 per day.	..	....
	6,132		188		2,294		7,992		310	

CLASS OF LABOUR.		BEAVER COUNTY DISTRICT.		WASHINGTON COUNTY DISTRICT.		GREENE COUNTY DISTRICT.		FRANKLIN DISTRICT.	Total number of Labourers.
Foremen, . .	9	$50 to $150 p. month.	90	$80 to $125 p. month.	*21	No record.	5	$60 to $75 p. month.	554
Pumpers or engineers, .	81	$8·33⅓ to $70 p. month	610	$15 to $60 p. month.	95	,,	69	$8 to $57·50 p. month.	6,245
Carpenters, . .	13	$2·50 per day.	30	$2·50 to $3 per day.	5	,,	15	$1·75 to $3 per day.	1,260
Rig builders, .	42	$110 to $225·50 p. rig.	198	$150 to $200 per rig.	5	,,	20	$35 to $80 per rig.	2,473
Drillers, . .	84	$70 to $90 p. month.	588	$1 to $1·50 per foot.	65	,,	59	50 to 60 cents p. foot.	5,082
Tool dressers, .	..	....	6	$5 per day.	..	....	2	$2·50 per day.	101
Labourers, . .	35	$1·39 to $2 per day.	252	$1·25 to $2·50 p. day.	92	,,	12	$1·50 to $2 per day.	2,563
Teamsters, . .	1	½ cent per gallon.	..	....	..	....	1	$1·50 per day.	257
Boys under 16 years,	..	....	..	....	..	....	..	....	26
Well cleaners, .	..	....	36	$2 to $5 per day.	5	,,	..	....	737
Sundry mechanics,	18	$61·39 per month.	21	$50 to $60 p. month.	2	,,	1	$5·27 per day.	206
Grand totals, .	6,415		2,019		2,584		8,176		19,504

* Estimated.

CAPITAL INVESTED IN THE PRODUCTION OF CRUDE PETROLEUM, VALUE OF MATERIALS USED IN PUMPING, CARING FOR AND OPERATING WELLS, AND AVERAGE CAPITAL PER WELL IN EACH OF THE DISTRICTS IN THE PENNSYLVANIA FIELDS IN 1889.

(Compiled from the Eleventh Census Report of the United States.)

DISTRICTS.	Total Capital.	Total value of Property, except Land.	Total value of Land.	Total Acreage.	Value material operating Wells.	Average Capital per Well.
Bradford, Allegany, ...	$32,288,195	$23,725,368	$8,562,827	182,861	$2,603,248	$1,982
Forest, ...	1,162,174	513,836	648,338	30,895	29,900	3,887
Warren, ...	10,680,618	6,709,094	3,971,524	88,486	1,022,966	2,558
Butler, Clarion, Venango, Armstrong, &c., . .	26,020,574	17,698,370	8,322,204	351,278	1,787,296	3,121
Allegheny, ...	2,070,926	1,331,050	739,876	31,971	215,096	6,949
Beaver and Smith's Ferry, ...	2,203,219	1,205,164	998,055	28,812	214,026	8,160
Washington, ...	12,238,107	9,534,291	2,703,816	112,137	2,454,446	9,933
Greene, ...	2,171,763	1,193,336	978,427	42,083	274,460	9,401
Franklin, ...	726,432	466,642	259,790	4,876	31,953	1,151
	$89,562,008	$62,377,151	$27,184,857	873,399	$8,633,391	$2,504

TOTAL CAPITAL INVESTED IN THE PRODUCTION OF CRUDE PETROLEUM IN THE PENNSYLVANIA FIELDS IN 1889, OTHER THAN THAT INVESTED IN LAND, COVERED BY THE ABOVE TABLE.

DISTRICTS.	Rigs. Well Engines, &c.	Tanks.	Tank Cars.	Pipe Lines.	Oil in Stock, December 31, 1889.	Other Property.	Total.
Bradford, Allegany, ...	$20,149,046	$534,594	$510	$681,549	$181,376	$2,178,293	$23,725,368
Forest, ...	406,559	15,911	495	42,755	7,668	40,448	513,836
Warren, ...	5,575,578	160,376	..	215,212	60,820	697,108	6,709,094
Butler, Clarion, Venango, Armstrong, &c., . .	16,654,912	421,192	5,250	233,300	70,676	313,040	17,698,370
Allegheny, ...	1,280,455	10,900	..	4,771	6,857	28,067	1,331,050
Beaver and Smith's Ferry, ...	1,134,572	21,046	..	2,632	18,904	28,010	1,205,164
Washington, ...	9,151,407	139,590	..	81,819	99,054	62,421	9,534,291
Greene, ...	1,148,225	13,750	..	2,762	950	27,650	1,193,336
Franklin, ...	435,441	10,255	1,000	4,128	..	15,818	466,642
	$55,936,104	$1,327,614	$7,255	$1,268,928	$446,306	$3,390,855	$62,377,151

QUANTITY AND VALUE OF CRUDE PETROLEUM EXPORTED FROM EACH OF THE SHIPPING PORTS OF THE UNITED STATES, FROM 1863 TO 1892.

YEAR ENDING JUNE 30.	PHILADELPHIA.		NEW YORK.		BALTIMORE.		BOSTON.		ALL OTHER PORTS.		TOTAL ALL PORTS.	
	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.
1864, . . .	2,087,114	670,774	8,443,631	3,605,780	338,324	140,032	..	..	256,364	124,045	11,125,433	4,540,631
1865, . . .	1,110,907	448,751	11,872,595	6,994,009	72,996	60,721	7,700	8,551	266,130	151,937	13,330,328	7,703,969
1866, . . .	5,096,037	1,639,991	11,290,623	4,616,171	170,442	82,583	5,602	1,801	241,283	132,330	16,803,987	6,472,876
1867, . . .	3,047,117	658,875	4,463,004	1,299,311	157,264	64,499	26,152	11,701	211,807	71,898	7,905,344	2,106,284
1868, . . .	3,778,871	622,677	5,910,462	811,374	764,121	255,702	30,939	5,725	232,840	95,182	10,717,233	1,790,660
1869, . . .	1,409,603	289,202	10,986,193	2,338,777	1,010,661	360,792	7,069	969	12,019	4,064	13,425,566	2,994,404
1870, . . .	3,005,916	608,415	6,573,688	1,364,062	656,726	191,146	1,000	500	165,984	73,169	10,403,314	2,237,292
1871, . . .	2,588,007	442,944	6,291,139	1,143,322	754,365	287,732	..	..	225,527	97,849	9,859,038	1,971,847
1872, . . .	5,951,795	999,064	7,403,322	1,270,145	197,339	35,568	1,700	488	5,612	1,846	13,559,768	2,307,111
1873, . . .	4,981,872	821,449	13,418,695	2,173,588	..	..	..	..	38,840	15,013	18,439,407	3,010,050
1874, . . .	4,395,953	473,020	13,367,003	1,624,697	..	..	..	..	13,463	1,979	17,776,419	2,099,696
1875, . . .	3,662,247	324,116	11,055,615	1,081,814	..	..	..	..	252	88	14,718,114	1,406,018
1876, . . .	8,663,564	873,592	10,675,183	1,218,916	1,178,080	127,353	..	..	3,570	407	20,520,397	2,220,268
1877, . . .	4,262,093	558,101	21,127,100	2,988,996	1,111,617	171,200	..	..	318,392	38,432	26,819,202	3,756,729
1878, . . .	4,809,278	471,871	19,347,620	1,911,694	1,803,138	176,816	..	..	976,691	133,637	26,936,727	2,694,018
1879, . . .	4,687,786	377,197	17,716,883	1,517,701	1,166,825	98,292	..	..	2,302,994	187,223	25,874,488	2,180,413
1880, . . .	2,730,147	160,549	24,034,260	1,652,200	..	..	500	65	1,533,090	114,393	28,297,997	1,927,207
1881, . . .	5,326,528	351,736	34,032,428	2,661,708	..	..	7,156	687	618,732	51,333	39,984,844	3,065,464
1882, . . .	4,454,946	288,581	36,326,586	2,802,955	..	..	..	..	523,465	39,975	41,304,997	3,129,511
1883, . . .	6,959,240	460,857	45,470,118	3,433,182	..	..	..	..	282,948	20,902	52,712,306	3,914,941
1884, . . .	5,557,310	400,833	61,622,893	4,901,448	..	..	..	..	6,126	693	67,186,329	5,302,974
1885, . . .	29,542,316	2,082,561	51,494,832	3,821,162	..	..	..	..	844	110	81,037,992	5,903,833
1886, . . .	33,452,742	2,327,344	46,545,119	3,513,491	25,995	1,626	10,000	830	212,907	16,286	80,246,763	5,859,577
1887, . . .	35,892,185	2,204,847	40,162,009	2,654,894	5,075	250	..	..	3,609	391	76,062,878	4,860,382
1888, . . .	39,908,874	2,530,308	45,517,847	3,238,053	..	..	..	..	112,004	13,647	85,538,725	5,782,008
1889, . . .	30,440,884	1,974,204	42,089,455	3,070,941	..	..	..	..	457,044	37,987	72,987,383	5,083,132
1890, . . .	45,039,903	2,803,070	48,962,415	3,816,964	..	..	..	..	1,448,335	124,201	95,450,653	6,744,235
1891, . . .	45,307,725	2,522,317	44,597,938	3,224,736	..	..	..	..	1,509,432	129,399	91,415,095	5,876,452
1892, . . .	65,898,042	2,908,987	35,380,720	2,074,140	..	..	..	..	2,314,005	118,713	103,592,767	5,101,840

PETROLEUM EXPORTS BY GRADES FROM 1863 TO 1892.

YEAR ENDING JUNE 30.	CRUDE.		NAPHTHA.		ILLUMINATING.		LUBRICATING.		RESIDUUM.		TOTAL.	
	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars	Gallons.	Dollars.
1864, .	9,980,654	3,864,187	438,107	154,091	12,791,518	6,764,411	..	..	..	..	23,210,369	10,782,689
1865, .	12,293,897	6,868,513	480,947	173,943	12,722,005	9,520,957	..	..	..	..	25,496,849	16,562,413
1866, .	16,057,943	6,015,921	673,477	188,825	34,255,921	18,626,141	..	..	..	..	50,987,341	24,830,887
1867, .	7,344,248	1,864,001	224,576	34,175	62,686,657	22,509,466	..	..	..	..	70,255,581	24,407,642
1868, .	10,029,659	1,564,933	1,517,268	267,873	67,909,961	19,977,870	..	..	..	..	79,456,888	21,810,676
1869, .	13,425,566	2,994,404	2,673,094	445,770	84,403,492	27,636,137	134,532	51,122	..	..	100,636,684	31,127,433
1870, .	10,403,314	2,237,292	5,422,604	564,864	97,902,505	29,864,193	6,871	2,611	..	..	113,735,294	32,668,960
1871, .	9,859,038	1,971,847	7,209,592	746,797	132,608,955	34,138,736	59,632	22,660	155,474	14,770	149,892,691	36,894,810
1872, .	13,559,768	2,307,111	8,092,635	932,160	122,539,575	30,566,108	541,419	211,287	438,186	41,724	145,171,583	34,058,390
1873, .	18,439,407	3,010,050	9,743,593	1,487,439	158,102,414	37,195,735	748,699	277,966	781,074	79,566	187,815,187	42,050,756
1874, .	17,776,419	2,099,696	9,737,457	1,038,622	217,220,504	37,560,995	1,244,305	404,243	1,827,798	142,299	247,806,483	41,245,815
1875, .	14,718,114	1,406,018	11,758,940	1,141,440	191,551,933	27,030,361	1,173,473	313,646	2,752,848	187,103	221,955,308	30,078,568
1876, .	20,520,397	2,220,268	14,780,236	1,442,811	204,814,673	28,755,638	963,442	303,863	1,581,401	193,206	243,660,152	32,915,786
1877, .	26,819,202	3,756,729	15,140,183	1,816,682	262,441,844	55,401,132	1,601,065	497,540	3,196,620	317,355	309,198,914	61,789,438
1878, .	26,936,727	2,694,018	16,416,621	1,411,812	289,214,541	41,513,676	2,304,624	639,381	3,968,790	316,087	338,841,303	46,574,974
1879, .	25,874,488	2,180,413	15,054,361	1,258,780	331,586,442	35,999,862	2,487,681	655,468	3,307,038	210,726	378,310,010	40,305,249
1880, .	28,297,997	1,927,207	18,411,044	1,192,229	367,325,823	31,783,575	5,162,835	1,039,124	4,767,000	276,490	423,964,690	36,218,625
1881, .	39,984,844	3,065,464	17,292,310	1,693,975	332,283,045	34,317,695	4,852,203	1,054,064	3,247,860	184,411	397,660,262	40,315,609
1882, .	41,304,997	3,129,511	20,313,098	1,809,143	488,213,033	44,588,854	5,508,100	1,492,396	3,716,362	212,802	559,954,590	51,232,706
1883, .	52,712,306	3,914,941	17,070,537	1,302,286	419,821,081	36,926,574	10,182,342	2,326,632	6,145,356	442,646	505,931,622	44,913,079
1884, .	67,186,329	5,302,974	15,045,411	1,072,651	415,615,693	38,195,349	10,515,535	2,179,595	5,297,124	352,679	513,660,092	47,103,248
1885, .	81,037,992	5,903,833	15,822,853	1,272,290	458,243,192	40,074,827	13,002,483	2,632,883	6,561,660	374,114	574,628,180	50,257,947
1886, .	80,246,763	5,859,577	12,311,197	997,420	469,471,451	40,634,331	12,526,069	2,519,615	3,226,272	188,901	577,781,752	50,199,844
1887, .	76,062,878	4,800,382	15,735,239	1,370,675	480,845,811	37,303,997	16,910,513	3,133,300	3,248,826	156,579	592,803,267	46,824,933
1888, .	85,538,725	5,782,008	12,066,921	992,281	456,487,221	36,215,410	22,889,529	3,975,377	1,369,242	77,333	578,351,638	47,042,409
1889, .	72,987,383	5,083,132	14,100,054	1,155,703	502,257,455	39,286,333	25,166,913	4,292,020	1,683,654	96,489	616,195,459	49,913,677
1890, .	95,450,653	6,744,235	12,937,433	1,134,799	523,295,090	38,640,638	30,162,522	4,763,347	2,645,800	120,070	664,491,498	51,403,089
1891, .	91,415,095	5,876,452	12,171,147	993,056	571,119,805	40,221,201	33,514,730	4,858,603	1,903,300	77,422	710,124,077	52,026,734
1892, .	103,592,767	5,101,840	12,727,978	912,921	564,896,658	33,541,224	33,591,076	5,203,350	663,500	46,657	715,471,979	44,805,992

SUMMARY OF STATEMENTS MADE JANUARY 10, 1893, RELATING TO BUSINESS OF VARIOUS PIPE LINES FOR MONTH ENDING DECEMBER 31, 1892.

(In barrels of 42 American gallons each.)

	Total Liabilities.	Gross Stock.	Sediment and Surplus.	Runs from Wells.	Other Receipts.	Regular Deliveries.	Other Deliveries.
National Transit Company, . . .	11,908,341.60	13,462,723.19	1,554,381.50	784,215.37	682,789.18	562,303.45	1,027,632.45
Southwest Pennsylvania Pipe Lines, .	1,755,863.57	1,942,544.20	186,680.63	575,725.60	50,602.68	1,231.60	503,322.08
The Eureka Pipe Line Company, . .	594,328.24	701,214.62	106,886.38	508,183.65	218,056.09	46,807.89	582,538.85
The Buckeye Pipe Line Company, Macksburg Oil, ...	422,141.62	438,648.84	16,507.22	196,851.67	2,139.68	6,442.51	204,715.75
Southern Pipe Line Company, . . .	209,192.65	227,319.71	18,127.06	....	517,428.54	538,473.89	....
New York Transit Company, . . .	584,782.77	758,505.62	173,722.85	....	955,118.40	1,187,425.85	....
	15,474,650.45	17,530,956.18	2,056,305.73	2,064,976.29	2,426,134.57	2,342,685.19	2,408,210.18

PIPE-LINE RUNS IN THE APPALACHIAN OIL FIELD IN 1893, BY LINES.

Name of Company.	Barrels.	Name of Company.	Barrels.
National Transit,	8,037,337	Chas. Miller,	36,724
Tidewater,	1,579,586	Elk,	280,870
Octave,	23,348	Producers' Pipe-line,	39,214
South-West,	5,740,856	Emery,	371,058
Franklin,	66,278	Mellon,	3,103,915
Western and Atlantic,	1,019,849	Eureka,	7,554,866
Producers' and Refiners' Pipe-line Company, Limited,	1,074,244	Buckeye—Macksburg,	2,075,115
		Total,	31,003,260

SHIPMENTS OF CRUDE PETROLEUM FROM THE LIMA-INDIANA FIELD.

Year.	Barrels.	Year.	Barrels.
1889	5,801,928	1892	16,504,880
1890	6,199,306	1893	14,651,643
1891	12,154,865		

SHIPMENTS OF CRUDE PETROLEUM, AND REFINED PETROLEUM REDUCED TO CRUDE EQUIVALENT, FROM THE EASTERN OHIO DISTRICT.

Year.	Barrels.	Year.	Barrels.
1889	276,432	1892	66,463
1890	578,203	1893	44,515
1891	141,839		

EXPORTS OF CRUDE PETROLEUM AND PETROLEUM PRODUCTS, IN GALLONS (AMERICAN), FOR THE FISCAL YEARS 1889-90 TO 1893-94, EACH YEAR ENDING JUNE 30TH. (Compiled by the Bureau of Statistics of the United States Treasury Department.

COUNTRIES.	1890.	1891.	1892.	1893.	1894.
CRUDE.					
Europe—					
France,	68,947,436	61,663,973	69,100,657	69,424,609	84,434,953
Germany,	1,188,266	3,107,137	5,247,209	4,182,963	4,877,593
Spain,	13,934,088	17,103,416	17,064,929	21,112,042	15,176,034
Other districts,	3,680,631	2,380,600	1,935,014	3,948,842	2,009,727
Total,	87,750,421	84,255,126	93,347,809	98,668,456	106,498,307
North America—					
Mexico,	2,217,846	3,854,176	3,499,514	5,508,769	8,026,189
Cuba,	4,913,330	3,300,455	6,316,406	6,955,315	6,865,549
Other districts,	36,806	4,338	425,348	548,068	534,304
Total,	7,167,982	7,158,969	10,241,268	13,012,152	15,426,042
All other countries,	532,250	1,000	3,690	22,900	2,000
Total crude,	95,450,653	91,415,095	103,592,767	111,703,508	121,926,349
REFINED.					
Naphthas.					
Europe—					
France,	4,195,704	2,831,929	1,561,284	4,080,839	3,764,569
Germany,	2,015,298	3,227,106	3,471,652	4,127,354	4,278,757
United Kingdom,	5,603,994	5,058,325	6,813,416	8,209,526	6,834,760
Other districts,	928,616	824,537	686,398	658,270	364,135
Total,	12,743,612	11,941,897	12,532,750	17,076,989	15,242,221
North America,	59,563	86,910	35,762	122,237	173,649
South America,	78,180	71,192	89,609	55,940	79,777
Asia and Oceania,	45,214	55,005	57,787	39,625	57,057
Africa,	10,864	16,143	12,070	9,214	3,050
Total,	193,821	229,250	195,228	227,016	313,533
Total naphthas,	12,937,433	12,171,147	12,727,978	17,304,005	15,555,754
Illuminating.					
Europe—					
Belgium,	41,391,323	32,397,015	31,471,121	33,541,439	36,312,974
Denmark,	7,147,115	9,135,048	7,019,575	12,262,308	9,290,251
France,	2,088,291	3,764,974	3,005,535	8,161,023	11,812,001
Germany,	140,264,089	162,187,071	133,417,314	119,277,484	86,388,785
Italy,	19,747,758	20,955,728	22,324,113	22,815,209	22,945,037
Netherlands,	47,315,526	54,879,032	76,607,780	51,298,480	31,868,189
Sweden and Norway,	11,772,106	8,957,350	11,150,824	16,312,912	9,848,074
United Kingdom,	66,393,246	81,028,529	94,901,777	180,996,321	274,555,010
Other districts,	7,464,013	8,759,531	6,450,040	8,654,660	7,232,024
Total,	343,583,460	382,064,273	386,357,079	453,319,916	490,252,345

EXPORTS OF CRUDE PETROLEUM AND PETROLEUM PRODUCTS—*Continued.*

COUNTRIES.	1890.	1891.	1892.	1893.	1894.
North America—					
British districts,	5,104,864	5,230,259	5,735,411	6,341,042	8,248,417
West Indies,	4,404,548	3,303,506	4,262,935	4,439,118	4,174,856
Other districts,	2,520,131	3,303,608	2,250,162	2,204,602	1,759,565
Total,	12,029,543	11,837,373	12,248,508	12,984,762	14,182,838
South America—					
Argentine Republic,	3,113,750	3,476,192	4,825,196	4,070,719	3,162,846
Brazil,	8,695,291	10,470,656	14,028,476	15,556,685	12,134,709
Uruguay,	3,492,158	3,165,880	4,293,400	2,882,105	2,520,571
Other districts,	6,236,596	4,792,161	6,827,814	6,041,571	5,503,680
Total,	21,537,795	21,904,889	29,974,886	28,551,080	23,341,806
Asia and Oceania—					
China,	13,072,000	27,160,660	17,370,000	27,874,200	40,377,296
Hong Kong,	11,150,220	10,804,630	16,529,790	12,758,800	16,888,820
East Indies,	63,456,071	63,285,770	55,907,410	57,404,175	85,907,557
Japan,	37,890,930	31,000,629	23,761,930	26,869,500	37,272,450
British Australasia,	7,976,572	10,260,955	10,376,260	11,053,991	11,821,881
Other districts,	3,982,465	4,680,690	3,095,546	2,637,250	2,944,958
Total,	137,530,258	147,168,474	127,041,536	138,597,976	195,212,962
Africa,	8,426,714	8,058,806	8,865,999	8,206,932	7,049,455
All other countries,	187,320	85,990	408,650	579,150	329,220
Total illuminating,	523,295,090	571,119,805	564,896,658	642,239,816	730,368,626
Lubricating.					
Europe—					
Belgium,	1,955,145	2,337,030	2,632,954	2,426,926	2,931,204
France,	3,088,183	3,948,257	2,461,722	2,426,659	3,050,547
Germany,	3,670,937	4,186,225	4,512,639	3,798,953	5,637,471
Italy,	510,622	591,996	414,971	788,805	1,356,340
Netherlands,	2,037,437	1,504,623	2,229,116	1,842,608	2,346,896
United Kingdom,	17,035,447	18,767,573	18,779,806	17,683,132	19,668,767
Other districts,	146,557	111,165	209,713	249,474	415,385
Total,	28,444,328	31,446,869	31,240,921	29,216,557	35,406,610
North America,	524,898	570,380	656,991	1,043,770	1,725,709
South America,	721,669	889,610	798,194	1,207,232	1,509,708
Asia and Oceania,	457,363	582,392	813,618	888,032	1,433,191
Africa,	14,264	25,479	81,352	77,266	115,359
Total,	1,718,194	2,067,861	2,350,155	3,216,300	4,783,967
Total lubricating,	30,162,522	33,514,730	33,591,076	32,432,857	40,190,577
Residuum (barrels).					
Europe,	10,017	9,058	6,361	10,404	2,056
North America,	42,141	28,833	6,622	2,202	2,973
All other countries,	758	175	287	276	..
Total residuum,	52,916	38,066	13,270	12,882	5,029

Exports of Crude Petroleum, Kerosene, and Naphtha from the United States, for the Year 1894.

(*Compiled from the Weekly Shipping Lists of Beling, Niemeyer, and Wessels.*)

	Exported in Bulk.			Exported in Barrels.			Exported in Cases.		
	Barrels Crude Oil.	Barrels Kerosene.	Barrels Naphtha.	Barrels Crude Oil.	Barrels Kerosene.	Barrels Naphtha.	Cases Crude Oil.	Cases Kerosene.	Cases Naphtha.
Aalborg,	..	..	..	..	4,400	..	..	..	..
Aarhus,	..	51,300	..	..	8,590	..	..	..	..
Aden and Bombay,	..	..	..	..	..	..	..	80,000	..
Alden and Bombayete,	..	..	..	..	..	..	..	83,345	..
Alexandria,	..	..	..	..	..	..	..	230,095	..
Algiers,	..	..	..	..	..	..	..	97,133	..
Alicante,	40,089	..	..	..	..	..	..	..	..
Alicante and Seville,	35,108	..	..	..	..	..	..	..	..
Allepy and Zanzibar,	..	..	..	..	..	..	..	40,000	..
Amoy,	..	..	..	..	..	..	..	224,524	..
Amsterdam,	..	145,811	..	..	..	..	..	..	..
Anjer,	..	..	..	..	..	..	..	714,436	..
Antwerp,	..	740,281	..	..	250	..	..	..	..
Avonmouth,	..	297,510	..	..	..	..	..	..	..
Banda,	..	..	..	..	..	..	..	10,791	..
Bangkok,	..	..	..	..	..	..	..	27,103	..
Banjamasin and Palembang,	..	..	..	..	..	..	..	36,250	..
Barcelona,	27,074	13,618	..	..	..	..	..	..	..
Barletta,	..	..	..	..	..	..	..	57,688	..
Belfast,	..	63,650	..	..	..	..	..	..	..
Bergen,	..	23,142	..	..	17,798	..	..	..	..
Bilbao,	40,397	..	..	..	..	..	..	..	..
Blaye,	111,650	..	..	9,275	7,682	10,759	..	..	..
Bombay,	..	..	..	..	..	..	..	756,918	..
Bone and Phillipeville,	..	..	..	..	..	..	..	20,900	..
Bostia,	..	..	..	..	..	..	..	37,300	..
Bremen,	..	26,200	..	..	..	23,333	..	..	1,000
Bristol,	..	..	..	..	10,745	..	..	..	..
Cagliari,	..	..	..	..	..	..	..	58,224	..
Calais,	141,972	56,785	..	..	..	..	..	..	..
Calcutta,	..	..	..	..	..	..	..	1,896,253	..
Cardiff,	..	38,140	..	..	5,409	1,945	..	..	..
Cette,	155,475	..	..	..	..	..	..	..	..
Chantenay,	..	..	..	..	..	4,490	..	..	..
Christiania,	..	119,316	..	..	20,782	200	..	..	..

EXPORTS OF CRUDE PETROLEUM, KEROSENE, AND NAPHTHA—*Continued.*

	Exported in Bulk.			Exported in Barrels.			Exported in Cases.		
	Barrels Crude Oil.	Barrels Kerosene.	Barrels Naphtha.	Barrels Crude Oil.	Barrels Kerosene.	Barrels Naphtha.	Cases Crude Oil.	Cases Kerosene.	Cases Naphtha.
Christiansand,	..	..	..	..	8,279	..	..	..	..
Coleraine,	..	..	..	..	3,900	..	..	..	..
Colombo,	..	..	..	..	..	..	..	38,917	..
Constantinople,	..	..	..	..	..	..	..	20,800	..
Continent (port not specified),	..	22,600	..	..	..	..	..	..	..
Copenhagen,	..	135,344	..	..	24,616	..	..	..	..
Cork,	..	..	..	..	17,000	..	..	..	..
Corunna,	5,495	..	..	..	..	..	..	..	..
Dantzig,	..	..	..	..	10,967	..	..	..	..
Dieppe,	75,092	37,239	..	21,710	21,814	4,816	..	..	..
Dover (for orders [1]),	14,000	4,888,945	59,285	..	1,231	..	..	21,000	..
Drontheim,	..	..	..	..	6,498	..	..	675	..
Dublin,	..	..	..	..	100,679	..	..	..	..
Dunkirk,	..	..	..	157,567	34,433	..	..	..	..
Exmouth,	..	..	..	..	20,049	5,839	..	..	..
Fiume,	24,029	..	..	..	..	..	..	..	..
Fredericia,	..	..	..	..	5,278	..	..	..	..
Friedrikshavn,	..	5,258	..	..	..	..	..	..	..
Galway,	..	..	..	..	3,916	..	..	..	..
Gefle,	..	..	..	..	9,151	450	..	500	..
Genoa (see also Tunis and Genoa),	..	..	..	..	..	..	..	469,055	..
Genoa and Leghorn,	..	..	..	..	..	..	..	30,000	..
Gibraltar,	..	28,000	..	..	..	..	..	77,060	..
Gothenburg,	..	..	..	..	25,598	499	..	..	..
Haiphong,	..	..	..	..	..	..	..	50,200	..
Havre,	185,369	..	..	..	..	..	..	..	..
Helsingborg,	..	..	..	..	6,877	..	..	..	..
Hernosand,	..	..	..	..	7,976	..	..	..	..
Hiogo,	..	..	..	..	..	..	..	1,395,164	..
Hodeidah,	..	..	..	..	..	..	..	70,998	..
Hong Kong,	..	..	..	..	..	..	..	1,361,369	..
Hudiksvall,	..	..	..	..	8,158	..	..	..	..
Hull,	..	230,062	..	..	..	..	..	..	..
Iloilo (see also Manila and Iloilo),	..	..	..	..	..	..	..	..	..
India, China, and Japan,	..	..	..	..	..	..	..	46,841	..
Ipswich,	..	..	..	..	..	..	..	101,300	..
Japan (see also India, China, and Japan,	..	..	..	..	3,008	..	..	126,954	..

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[1] The whole of these shipments went to the Continent.

EXPORTS OF CRUDE PETROLEUM, KEROSENE, AND NAPHTHA—*Continued.*

	Exported in Bulk.			Exported in Barrels.			Exported in Cases.		
	Barrels Crude Oil.	Barrels Kerosene.	Barrels Naphtha.	Barrels Crude Oil.	Barrels Kerosene.	Barrels Naphtha.	Cases Crude Oil.	Cases Kerosene.	Cases Naphtha.
Java,	..	..	..	..	..	..	..	762,493	..
Karlskrona,	..	..	..	..	3,647	..	..	..	..
Kjoge,	..	..	..	..	3,044	..	..	..	..
Kobe,	..	..	..	..	..	..	..	95,626	..
Kolding,	..	..	..	..	5,950	..	..	..	..
Konigsberg,	..	..	..	..	8,108	..	..	..	..
La Pallice,	20,000	..	..	6,876	..	..	..	..	..
Las Palmas,	..	..	..	..	..	..	..	21,202	..
Limerick,	..	..	..	..	27,909	..	..	..	..
Lisbon,	..	..	..	..	30,157	..	..	71,645	..
Liverpool,	..	493,291	..	..	11,507	42,673	..	..	12,500
London,	..	1,031,928	..	..	77,541	81,430	..	..	5,200
Londonderry,	..	..	..	..	13,244	..	..	..	..
Macassar,	..	..	..	..	..	..	..	39,063	..
Madras,	..	..	..	..	..	..	..	86,200	..
Malaga,	..	..	..	4,758	..	..	..	..	..
Malmo,	..	..	..	..	5,075	..	..	..	..
Manila and Iloilo,	..	..	..	..	..	..	..	54,250	..
Marseilles,	..	..	..	66,094	15,255	..	..	..	..
Messina,	..	..	..	..	..	..	..	121,680	..
Molucca Islands,	..	..	..	..	..	..	..	43,479	..
Nagasaki,	..	..	..	..	..	..	..	511,791	..
Naples,	..	..	..	..	9,560	..	..	172,152	..
Nordenham,	66,107	31,125	..	..	..	..	..	..	..
Nordkoping,	..	..	..	..	7,618	400	..	..	..
Oporto,	..	..	..	..	10,721	..	..	44,600	..
Oran,	..	..	..	..	..	..	..	31,028	..
Padang,	..	..	..	..	..	..	..	47,300	..
Palermo,	..	..	..	..	..	..	..	127,055	..
Palma,	26,965	..	..	..	..	..	..	..	..
Passages,	11,622	6,016	..	..	..	..	..	..	..
Patras and Piraeus,	..	..	..	..	..	..	..	131,281	..
Penang,	..	..	..	..	..	..	..	119,052	..
Plymouth,	..	59,430	..	..	4,700	..	..	..	..
Port de Bouc,	..	..	..	..	35,610	1,465	..	..	..
Portishead,	..	..	..	..	3,223	14,577	..	..	3,000
Porto Empedocle,	..	..	..	..	..	..	..	59,800	..

EXPORTS OF CRUDE PETROLEUM, KEROSENE, AND NAPHTHA—*Continued.*

	Exported in Bulk.			Exported in Barrels.			Exported in Cases.		
	Barrels Crude Oil.	Barrels Kerosene.	Barrels Naphtha.	Barrels Crude Oil.	Barrels Kerosene.	Barrels Naphtha.	Cases Crude Oil.	Cases Kerosene.	Cases Naphtha.
Port Said,	. .	32,000	. .	. .	. .	. .	. .	. .	. .
Rangoon,	. .	. .	. .	. .	. .	. .	. .	167,633	. .
Rotterdam,	. .	277,966	. .	. .	. .	. .	. .	. .	. .
Rouen,	425,544	. .	. .	. .	. .	. .	. .	. .	. .
Rouen and St. Loubes,	. .	31,797	. .	. .	. .	. .	. .	.	. .
Sables d'Olonne,	22,834	. .	. .	822	. .	. .	. .	. .	. .
Saigon,	. .	. .	. .	. .	. .	. .	. .	103,289	. .
St. Loubes,	57,676	. .	. .	. .	. .	. .	. .	. .	. .
St. Louis du Rhone,	. .	19,485	. .	20,372	3,761	. .	. .	. .	. .
Santander,	33,277	. .	. .	. .	. .	. .	. .	. .	. .
Saraholmen,	. .	. .	. .	. .	2,647	. .	. .	. .	. .
Savona,	. .	193,654	. .	. .	. .	. .	. .	. .	. .
Seville,	23,229	. .	. .	. .	. .	. .	. .	. .	. .
Shanghai,	. .	. .	. .	. .	. .	. .	. .	2,838,353	. .
Sicily,	. .	. .	. .	. .	. .	. .	. .	30,800	. .
Skaalevig,	. .	24,900	. .	. .	. .	. .	. .	. .	. .
Sligo,	. .	. .	. .	. .	4,859	. .	. .	. .	. .
Sodertelge,	. .	. .	. .	. .	2,052	3,000	. .	. .	. .
Southampton,	. .	. .	. .	. .	15,901	. .	. .	. .	. .
South Shields,	. .	89,471	. .	. .	. .	. .	. .	. .	. .
Stettin,	. .	50,095	. .	. .	25,436	. .	. .	. .	. .
Stockholm,	. .	44,000	. .	3,500	31,931	1,399	. .	23,120	. .
Sunderland,	. .	30,270	. .	. .	. .	. .	. .	. .	. .
Svendborg,	. .	. .	. .	. .	2,658	. .	. .	. .	. .
Tralee,	. .	. .	. .	. .	3,104	. .	. .	. .	. .
Tunis and Genoa,	. .	. .	. .	. .	. .	. .	. .	35,710	. .
Uddevalla,	. .	. .	. .	. .	6,723	499	. .	. .	. .
Valencia,	9,116	. .	. .	. .	. .	. .	. .	. .	. .
Venice,	. .	116,117	. .	. .	. .	. .	. .	. .	. .
Vigo,	5,456	. .	. .	5,379	. .	. .	. .	. .	. .
Vola,	. .	. .	. .	. .	. .	. .	. .	68,000	. .
Wasa,	. .	. .	. .	. .	1,793	250	. .	750	400
Waterford,	. .	. .	. .	. .	4,901	. .	. .	. .	. .
Yokohama,	. .	. .	. .	. .	. .	. .	. .	1,549,506	. .
Zanzibar,	. .	. .	. .	. .	. .	. .	. .	94,151	. .
	1,558,476	9,454,740	59,285	296,353	774,319	198,024	Nil.	15,632,802	22,100

CANADA.

The production of crude petroleum in Canada, for the years 1888 to 1894, calculated from the quantities of refined oil inspected, on the basis of a yield of 38 per cent. of refined oil, was as follows :—

Year.	Imperial gallons.	
	Refined inspected.	Crude equivalent.
1888,	9,545,895	25,120,776
1889,	9,462,834	24,902,195
1890,	10,121,210	26,634,763
1891,	10,270,107	27,026,597
1892,	10,370,707	27,291,334
1893,	10,618,804	27,944,221
1894,	11,027,082	29,018,637

According to the returns received by the Canadian Geological Survey, the quantities of petroleum products manufactured in the Canadian refineries, during the year 1894, were as follows :—

Illuminating oils,	11,289,741	imperial gallons.
Benzine and naphthas,	645,031	,, ,,
Paraffin oil,	1,282,749	,, ,,
Gas and fuel oils,	7,323,374	,, ,,
Lubricating oils and tar,	1,801,174	,, ,,
Paraffin wax,	1,950,172	pounds.

RUSSIA.

The following statistics of the Russian petroleum industry are given in poods (1 pood = 36·1127 lbs. avoirdupois):—

Note.—In comparing the production of crude petroleum in Russia with the production of crude petroleum in the United States, 8 poods may be taken as the equivalent of the American "barrel" unit.

Production of Crude Petroleum in the Apsheron Peninsula, and Exports of Petroleum Products from Baku.

Years.	Production of crude oil.	Exports of petroleum products.			
		Kerosene.	Lubricating oil.	Residuum.	Total exports of all petroleum products.
	Million poods.				
1880,	25	8·0	..	7·0	15·0
1881,	40	12·8	..	9·3	22·1
1882,	50	13·5	0·3	18·2	31·8
1883,	60	15·0	1·2	18·0	35·0
1884,	90	22·0	1·5	29·2	52·7
1885,	116	30·0	1·6	33·9	65·5
1886,	150	35·0	1·7	36·2	72·9
1887,	165	44·0	2·3	41·5	87·8
1888,	192	50·0	2·6	58·5	111·1
1889,	205	61·1	3·3	88·6	153·1
1890,	239	67·3	4·6	97·1	169·0
1891,	289	74·0	5·1	103·4	182·5
1892,	298	78·7	5·6	116·8	201·1
1893,	337	85·9	5·8	143·5	248·2
1894,	304	71·2	4·9	198·6	288·4

Note.—For the greater part of the recent statistics of the Russian petroleum industry, the author is indebted to Dr. Paul Dvorkovitch.

EFFECTIVE PRODUCTION[1] IN THE DIFFERENT DISTRICTS.

	Million poods.					
	1889.	1890.	1891.	1892.	1893.	1894.
Balakhany, . .	68·9	63·3	74·2	57·5	57·8	59·0
Sabountchi, . .	105·6	143·5	168·5	154·7	146·3	143·0
Romany, . . .	..	1·5	13·0	41·0	73·1	61·7
Bibi-Eibat, . .	17·8	18·0	23·9	33·3	47·5	33·8
Total, . .	192·3	226·3	274·6	286·5	324·7	297·5

[1] After deduction of oil lost by leakage and evaporation, used as fuel, &c.

PRODUCTION, DISTINGUISHING BETWEEN PUMPING WELLS AND FLOWING WELLS.

	Million poods.					
	1889.	1890.	1891.	1892.	1893.	1894.
Pumping wells,	149·7	176·6	235·4	210·8	215·5	235·7
Flowing wells,	42·6	49·7	39·2	75·7	109·2	61·8

NUMBER OF PRODUCING WELLS IN THE APSHERON PENINSULA.

1889, ...	278	1891, ...	458
1890, ...	356	1892, ...	448

	1893.	1894.
Producing wells, ...	458	541
Wells in course of drilling, ...	175	204
Wells deepened, ...	102	101
Wells commenced, ...	60	103

NUMBER OF PRODUCING WELLS IN THE DIFFERENT DISTRICTS.

	1893.	1894.
Balakhany, ...	175	468
Sabountchi, ...	224	
Romany, ...	33	48
Bibi-Eibat, ...	26	25

AVERAGE PRODUCTION PER WELL PER ANNUM, IN POODS.

	1893.	1894.
Balakhany,	330,476	....
Sabountchi,	648,610	....
Romany,	2,216,556	1,285,400
Bibi-Eibat,	1,826,720	1,312,000
General average,	709,089	550,000

STOCKS.

	Poods.	
	1893.	1894.
Crude oil—at oil fields,	16,300,000	19,600,000
„ „ Baku,	13,100,000	14,900,000
Kerosene,	8,200,000	10,300,000
Lubricating oil,	700,000	900,000
Residuum,	32,000,000	37,800,000

EXPORTS OF PETROLEUM PRODUCTS FROM BAKU.

	Million poods.			
	1889.	1890.	1891.	1892.
By the Caspian Sea,	110·2	118·7	132·6	145·1
By the Transcaucasian Railway,	47·4	57·2	61·8	67·8

EXPORTS OF CRUDE PETROLEUM FROM BAKU.

	Thousand Poods.		Thousand Poods.
1889,	4,185	1891	11,594
1890,	6,484	1892	11,532

EXPORTS FROM BAKU.

	Million poods.					
	Crude Oil.		Kerosene.		Residuum.	
	1893.	1894.	1893.	1894.	1893.	1894.
By the Caspian Sea,	..	..	29·6	22·0	133·0	182·8
By the Transcaucasian Railway,	..	..	56·3	48·3	10·5	10·8
Total,	12·2	16·4	85·9	71·2	143·5	193·6

Shipments from Batoum.

	Poods.	
	1893.	1894.
Austria,	6,686,034	6,378,203
Algiers and Tunis,	110,372	..
Belgium,	2,044,754	3,249,477
Corsica and Malta,	33,550	..
Danubian Countries,	641,337	446,296
England,	6,467,555	7,393,924
Egypt,	288,819	770,096
Eastern Countries,	16,392,835	12,009,034
France,	1,720,103	3,628,681
Germany,	679,884	1,539,988
Greece,	..	38,526
Holland,	..	301,724
Italy,	1,411,927	530,989
Port Said (transhipment),	4,483,606	..
Russian ports,	6,792,000	6,985,302
Turkey,	5,858,554	2,690,664
Total,	53,618,830	45,996,904

Stocks of Crude Petroleum and Petroleum Products at Baku, including Quantities in Tanks connected with Pipe Lines, on 1st January, 1895.

	Poods.		
	At the Refineries.	At the Stations.	Total.
Kerosene—			
Refined—Light,	3,817,547	627,599	3,445,146
,, Heavy,	..	..	14,000
Distillate—Light,	..	..	1,357,001
,, Heavy,	..	..	38,000
Benzine,	..	..	33,008
Lubricating Oils—			
Refined,	..	..	573,730
Unrefined,	..	..	689,393
Astatki,	23,043,585	3,286,514	26,330,109
Goudron,[1]	..	..	99,665
Crude petroleum,	8,904,277	612,057	9,516,334
Caustic soda residuals,	..	..	70,000

[1] Residuum (sp. gr. about 0·945) from distillation of lubricating oils.

PARTICULARS OF PLANT AT THE BAKU REFINERIES (113 IN NUMBER), AS ON THE 1ST JANUARY, 1895, BASED ON THE REPORTS OF THE ENGINEERS OF THE EXCISE INSPECTION.

Number and kind of appliances.	Capacity in poods.
Stills for continuous distillation—	
218 for kerosene,	299,200
24 for oils,	12,800
8 for benzine,	1,000
Stills for intermittent distillation—	
658 for kerosene,	471,842
156 for oils,	90,453
19 for benzine,	9,809
Storage tanks—	
376 for kerosene distillate,	3,096,260
140 for oil distillate,	869,346
43 for benzine distillate,	77,194
Acid mixing tanks (agitators)—	
133 for kerosene,	291,364
59 for oil,	49,152
4 for benzine,	278
Caustic soda mixing tanks (agitators)—	
135 for kerosene,	288,218
87 for oil,	59,800
4 for benzine,	268
130 air compressors, &c., for mixing-tanks.	
Settling tanks—	
161 for kerosene,	505,343
216 for oil,	194,780
9 for benzine,	5,398
968 steam pumps.	
10 hand pumps.	
59 donkey pumps (for feeding steam boilers).	
Storage tanks—	
256 for finished kerosene,	139,222,278
101 for finished oil,	918,663
12 for finished benzine,	42,976
117 (earthen) for astatki,	92,072,615
138 lined with stone,	10,484,468
72 lined with iron,	1,167,596

There were altogether 471 steam boilers in use.

PRODUCTION OF CRUDE PETROLEUM IN RUSSIA, IN GOVERNMENTS AND PROVINCES OTHER THAN BAKU, IN 1889 AND 1890.

Governments and Provinces.	1889.	1890.
	Poods.	Poods.
Kouban,	1,381,942	1,813,327
Trans-caspian region,	286,400	285,000
Tersk,	275,721	370,800
Tiflis,	55,296	46,444
Daghestan,	3,955	2,780
Tauride,	3,603	29,168
Elisabetpol,	3,000	11,000
Fergan,	1,425	2,106
Total,	2,011,342	2,560,625

UNITED KINGDOM.

SHIPMENTS OF REFINED PETROLEUM OIL (KEROSENE) FROM AMERICA AND RUSSIA TO THE UNITED KINGDOM.

(Compiled by Henry Funck & Co.)

Year.	Ports.	American.	Russian.	Total.
1894	Barrow-in-Furness, . .	..	10,800 barrels.	10,800 barrels.
,,	Belfast, ...	63,890 barrels.	67,709 ,,	131,599 ,,
,,	Bristol and Avonmouth, .	310,953 ,,	..	310,953 ,,
,,	Cardiff, ...	40,339 ,,	13,900 ,,	54,239 ,,
,,	Coleraine, ...	3,900 ,,	..	3,900 ,,
,,	Cork, ...	16,986 ,,	..	16,986 ,,
,,	Dublin, ...	101,030 ,,	..	101,030 ,,
,,	Exeter and Exmouth, .	18,429 ,,	..	18,429 ,,
,,	Galway, ...	3,916 ,,	..	3,916 ,,
,,	Hull, ...	242,631 ,,	..	242,631 ,,
,,	Ipswich, ...	3,008 ,,	..	3,008 ,,
,,	Limerick, ...	32,449 ,,	..	32,449 ,,
,,	[1] Liverpool and Birkenhead,	517,832 ,,	127,793 ,,	645,625 ,,
,,	London, ...	1,132,750 ,,	351,263 ,,	1,484,013 ,,
,,	Londonderry, . . .	13,244 ,,	..	13,244 ,,
,,	Plymouth, ...	59,919 ,,	..	59,919 ,,
,,	Portishead, ...	3,231 ,,	..	3,231 ,,
,,	Shields, ...	109,134 ,,	6,650 ,,	115,784 ,,
,,	Sligo, ...	4,859 ,,	..	4,859 ,,
,,	Southampton, . . .	7,640 ,,	..	7,640 ,,
,,	Sunderland, . . .	37,070 ,,	..	37,070 ,,
,,	Tralee, ...	3,104 ,,	..	3,104 ,,
,,	Waterford, ...	9,922 ,,	..	9,922 ,,
		2,736,236 barrels.	578,115 barrels.	3,314,351 barrels.
1893	Various ports, . . .	2,209,619 barrels.	743,094 barrels.	2,952,713 barrels.
1892	,, ,, . . .	1,711,089 ,,	807,600 ,,	2,518,689 ,,
1891	,, ,, . . .	1,647,772 ,,	830,863 ,,	2,478,635 ,,
1890	,, ,, . . .	1,357,122 ,,	787,529 ,,	2,144,651 ,,
1889	,, ,, . . .	1,355,590 ,,	771,227 ,,	2,126,817 ,,
1888	,, ,, . . .	1,286,148 ,,	549,126 ,,	1,835,274 ,,
1887	,, ,, . . .	1,444,350 ,,	188,461 ,,	1,632,811 ,,
1886	,, ,, . . .	1,363,801 ,,	46,814 ,,	1,410,615 ,,
1885	,, ,, . . .	1,367,720 ,,	70,149 ,,	1,437,869 ,,
1884	,, ,, . . .	927,919 ,,	17,078 ,,	944,997 ,,
1883	,, ,, . . .	1,329,004 ,,	502 ,,	1,329,506 ,,

[1] Exclusive of shipments of oil in barrels by general cargo steamers.

PRODUCTION OF CRUDE PETROLEUM IN THE UNITED KINGDOM FROM THE YEAR 1886.

(From the Official returns).

Year.	Quantity.
1886, ...	43 tons.
1887, ...	66 ,,
1888, ...	35 ,,
1889, ...	30 ,,
1890, ...	35 ,,
1891, ...	100 ,,
1892, ...	218 ,,
1893, ...	260 ,,
1894, ...	49 ,,

AUSTRIA-HUNGARY.

GALICIA.

PRODUCTION OF CRUDE PETROLEUM IN GALICIA FROM 1883 TO 1894.

Years.	Production.
1883,	166,500 barrels.
1884,	233,000 ,,
1885,	333,000 ,,
1886,	433,000 ,,
1887,	532,000 ,,
1888,	665,000 ,,
1889,	746,000 ,,
1890,	816,000 ,,
1891,	1,083,168 ,,
1892,	1,096,242 ,,
1893,	1,192,016 ,,
1894,	1,200,000 ,,

Note.—The official reports, on which the above figures are based, give the quantities in metre centners (of 100 kilos.), and the barrel has been taken as equivalent to 1½ metre centner.

CONSUMPTION OF REFINED PETROLEUM IN AUSTRIA-HUNGARY.

According to information received by the author from Her Majesty's Consul General in Vienna, the consumption of *refined* petroleum in Austria-Hungary amounted to 1,860,000 metre centners (1,240,000 barrels) in 1894.

PARTICULARS OF GALICIAN PETROLEUM WELLS.

	1891.	1892.
Total number of excavated shafts,	1,111	1,005
Number of shafts being sunk afresh,	30	38
Number of shafts producing oil,	274	209
Total number of drilled wells,	1,412	1,385
Number of wells being drilled,	185	192
Number of drilled wells from which the oil is being raised by manual labour,	318	253
Number of drilled wells from which the oil is being raised by steam pumps,	463	573
Number of sets of hand-drilling tools in use,	34	41
Number of sets of steam-drilling tools in use,	165	156
Number of hand-pumps in use,	295	240
Number of steam-pumps in use,	94	88
Aggregate length of pipe-lines, in kilometres,	70·7	76·3
Aggregate length of artesian casing in drilled wells, in metres,	132,000	217,000
Aggregate length of rivetted sheet-iron casing in drilled wells, in metres,	111,000	134,000
Number of iron tanks in use,	49	59
Number of wooden tanks in use,	642	634
Number of workmen employed,	3,275	3,173

Detailed Statement relative to the Mineral Oil Refineries in Austria-Hungary, giving the respective amounts of Taxation and quantities produced in the Calendar Years, 1891 to 1893. Compiled by Hans Urban from Statistical Reports.

	Petroleum Tax in Standard Austrian Gulden.			Production in Metre Centners (of 100 kilos.).		
	1893.	1892.	1891.	1893.	1892.	1891.
Lower Austria.						
Wien-Floridsdorfer Mineralölf., Donaufeld, Wien,	601,806	783,302	661,742	92,586	113,585	101,806½
Gustav Wagenmann, Wien X.,	374,076	385,739	452,183	57,550	59,344	69,506½
Küstenland.						
Triester Mineralöl-Raffinerie, Trieste,	923,799	643,972	....	142,123	99,073	....
Bohemia.						
David Fanto & Co., Pardubitz,	597,755	618,158	589,840	91,962	95,101	90,745½
Ofenheim & Co., Zabor-Elbeteinitz,	203,269	207,750	197,164	31,272	31,961½	30,383
Dr. Friedrich Pilz, Theussau-Falkenau,	64	167	412	10	25½	63½
Silesia.						
Max Böhm & Co., Privos-Mähr.-Ostrau,	421,787	460,252	287,057	56,333	70,808	44,163
Mineralöl-Raffinerie A.-G., Oderberg,	366,162	410,492	387,737	64,890	63,152½	59,652
Galicia.						
I. Galiz. Petroleum-Industrie-A.-G., Peczenizyn,	414,024	311,332	372,568	63,696	47,897	57,318
Bergheim & Mac Garvey, Mariampole-Gorlice,	401,705	414,513	421,924	61,801	63,771	64,911½
Gartenberg & Co., Kolomea,	236,466	203,132	224,050	36,379	31,251	34,469
Gartenberg & Co., Nieglowice-Jaslo,	210,001	270,987	192,735	32,308	42,613½	29,651½
Adam Skrzynsky, Libusza-Biecz,	205,034	203,027	203,740	31,542	31,251	31,345
Jadwiga Straszewska, Lipinki,	155,837	136,562	125,997	23,975	21,010	19,384
Gartenberg & Co., Drohobycz,	146,509	134,296	139,978	22,540	20,661	21,535
Nikolaus Feodorowicz. Ropa,	119,144	128,004	114,208	18,330	19,785	17,580
Wlad. Fibich & S. Stawiarski, Chorkówka-Krosno,	86,326	129,224	49,323	13,281	19,881	7,588
Jacob Alexandrowicz, Gorlice,	69,082	57,236	61,011	10,629½	8,808	9,386½
Endzweig & Fischer, Dukla,	46,988	50,624	41,527	7,229	9,173	6,389
Isaak Reich, Cergowa-Dukla,	40,151	39,239	35,430	6,177	6,037	5,451
Efraim Wertheimer, Gorlice,	39,885	47,436	49,344	6,136	7,298	7,591½
Samuel Ehrenberg, Senkowa-Gorlice,	37,095	35,610	26,465	5,799	5,478	4,072
Anglo-österr. Bank, Schodnica,	37,508	32,067	23,751	5,770½	4,933½	3,653
Kallmann Nebenzahl Strzózówka-Gorlice,	37,319	43,631	53,353	5,741	6,712½	8,208
Brust & Ehrenreich, Dukla,	37,051	36,951	46,220	5,700	5,085	7,111
Leisor Griffel, Pasieczna Nadworna,	32,179	24,945	33,009	4,951	3,838	5,075
Leisor Hoffmann, Hubicze-Drohobycz,	32,044	28,943	26,826	4,930	4,453	4,127
Sholto Douglas, Klenczany-Marcinkowice,	28,758	18,148	16,400	4,424	2,792	2,523
F. Vinzenz, Sopow-Kolomea,	28,741	65,029	56,210	4,422	10,004½	8,649
Feuerstein & Co., Drohobycz,	28,613	20,115	19,144	4,402	3,094½	2,945
Leib Lautmann, Zarzecze-Delatyn,	28,339	18,576	14,641	4,360	2,858	2,252½
Hersch Bloch, Werbiaz-Kolomea,	26,502	22,044	28,013	4,077	8,891	4,310
Isaak Gleicher, Gorlice,	23,098	27,861	24,130	3,558	4,980½	3,712

DETAILED STATEMENT RELATIVE TO THE MINERAL OIL REFINERIES IN AUSTRIA-HUNGARY—*Continued.*

	Petroleum Tax in Standard Austrian Gulden.			Production in Metre Centners (of 100 kilos.).		
	1893.	1892.	1891.	1893.	1892.	1891.
J. Friedmann, Kolomea,	18,293	11,146	23,002	2,814	1,715	3,539
Naftali Bodner, Ropica polska-Gorlice,	14,999	15,478	15,914	2,307	2,381	2,448
Zacharias Händel, Drohobycz,	13,017	8,699	10,224	2,003	1,338	1,573
Weiser & Co., Werbiaz-Kolomea,	12,896	13,038	11,046	1,984	2,006	1,699½
J. Kreisberg, Mykietynce-Pystin,	10,616	18,133	10,241	1,633	2,790	1,575
Chaskel Gleicher, Ropica polska-Gorlice,	10,333	10,319	7,070	1,590	1,588	1,088
Glanzmann & Co., Strzelbice-Stara Miasto,	9,752	9,038	9,003	1,500	1,390½	1,385
Salomon Kreppel, Lisznia Drohobycz,	7,958	6,549	8,988	1,224	1,007½	1,383
Baron Ferd. Brunicki, Klenczany-Marcinkowice,	7,744	7,779	6,924	1,191	1,197	1,065
Salomon Backenroth, Derezyce-Drohobycz,	4,926	1,407	840	758	215	129
Benjamin Mermelstein, Boryslaw,	3,874	7,099	5,797	596	1,092	892
Schepsel Rechter, Mraznica-Boryslaw,	2,033	1,393	883	313	214	136
Moses Wertheimer, Sokol-Gorlice,	1,335	562	10,060	205	86½	1,640
Osias Rymald, Chyrow,	1,294	244	829	190	37½	127½
Salomon Zins, Grybow,	676	45	....	104	7	....
Bukowina.						
Naftalie Ziefel, Mittoka-Dragomirna,	16,660	23,218	....	2,563	3,572	2,643½
Hungary.						
I. ung. Petroleum-Industrie-Act.-Ges., Budapest,	3,274,666	3,197,395	3,034,843	503,795	491,907	466,809
Mineralöl-Raffinerie-Act.-Ges., Fiume,	871,007	906,305	966,335	134,001	139,432	148,667
Siebenbürger Petr.-Raff.-A.-G., Kronstadt,	353,314	318,800	323,340	54,356	49,046	49,754
Mineralöl-Fabriks-Actiengesellschaft, Budapest,	267,967	255,346	316,797	41,226	39,284	48,738
Petroleum-Fabriks-Actiengesellschaft, Orsova,	263,348	275,882	275,025	40,515	42,443	42,312
Oesterr.-ung. Staatseisenbahn-Ges., Oravicza,	237,673	217,707	217,707	36,565	33,493	33,493½
Adolf Baruch, Maros-Vásárhely,	60,907	52,273	50,034	9,370	8,818	8,805
C. G. Joannides, Kronstadt,	52,069	57,315	57,232	8,010½	8,042	7,697½
Dr. Ferdinand Otroban, Kronstadt.	29,051	28,890	27,326	4,469	4,446	4,204
Salomon Grünfeld, Kronstadt,	27,552	29,341	28,213	4,469	4,514	4,340½
Jacob Nebenzahl, Krasznibrod,	3,741	....	....	576½	....	....
Mineralöl- & Asphalt-Actien-Ges., Tatoros,	1,662	....	....	255½	....	....
Stephan Popper, Ozokerit,	718	....	....	110½	....	....
Total production in—						
Lower Austria,	975,882	1,124,041[1]	1,113,925[1]	150,134	172,929½[1]	171,373[1]
Küstenland,	923,799	643,973	....	142,123	99,073	....
Bohemia,	801,088	826,075	787,422	123,244	127,088	121,142
Silesia,	787,949	870,744	674,794	121,223	133,960½	103,814
Galicia,	2,668,735	2,630,008	2,555,571	410,575	404,617	393,165
Bukowina,	16,660	23,218	17,182	2,563	3,572	2,643½
Austria (Cis-Leitha),	6,174,131	6,118,058	5,148,894	949,864	941,240	792,137
Hungary (Trans-Leitha),	5,443,681	5,339,263	5,297,120	837,489	986,768	821,425
The Austro-Hungarian Realm,	11,617,794	11,457,321	10,446,044	1,787,353	1,762,763	1,607,079

The yield of the tax in 1893 shows an excess of 160,473 florins over 1892 (corresponding to an increased production of 24,688 metre centners), an excess of 1,171,760 florins over 1891 (increased production 180,269 metre centners), and an excess of 1,915,064 florins over 1890 (increased produced 294,622 metre centners).

[1] The yield of the manufactories that have in the interim ceased working is included in these totals of tax and production.

IMPORTS OF PETROLEUM INTO AUSTRIA-HUNGARY IN THE YEARS 1892 TO 1894.

Description of Mineral Oil.	Commercial value in 1894. (In standard Austrian florins per 100 kilos.)	Total value of the imports in standard Austrian florins.		Total weight in metre centners (of 100 kilos).								
		1893.	1894.	1892.	1893.				1894.			
					From Russia.	From the United States.	From other countries.	Total.	From Russia.	From the United States.	From other countries.	Total.
Crude, heavy,	3·35	4,107,010	3,599,708	1,078,569	1,233,552	..	..	1,235,018	1,028,201	..	..	1,028,488
From Roumania,	2·55	409,068	486,560	187,111	..	..	..	160,419	..	..	..	176,931
Crude, light,	3·80	254,719	213,093	89,877	..	74,917	..	74,926	..	56,077	..	56,077
Crude, suitable for lighting,	6·95	1,745	632	126	..	..	..	251	..	..	..	91
Refined or semi-refined—												
Heavy, dark,	6	197,766	151,350	20,234	21,132	9,388	..	32,961	11,859	12,282	..	25,225
Heavy, pale,	7·50	135,294	246,165	12,416	13,769	4,486	..	18,039	31,064	1,306	..	32,822
Heavy lubricating oil,	8	582,128	505,376	61,808	47,207	20,149	..	72,766	36,300	20,795	..	63,172
Light,	7	307,090	342,776	50,158	..	31,274	12,596	43,870	..	39,840	9,128	48,968
For industrial purposes,	6·50	20	..	44	..	..	..	3	..	..	..	..

EXPORTS OF PETROLEUM FROM AUSTRIA-HUNGARY IN THE YEARS 1892 TO 1894.

Description of Mineral Oil.	Value 1894. (In standard Austrian florins per 100 kilos.)	Commercial value in standard Austrian florins.			Total exports in metre centners (of 100 kilos.).		
		1892.	1893.	1894.	1892.	1893.	1894.
Crude mineral oils,	3·50	20,161	21,456	34,115	5,700	6,130	9,747
Refined mineral oils,	5·75	24,278	17,632	11,943	3,884	3,006	2,077
Lubricating oils,	7	14,259	34,174	24,234	1,901	4,882	3,402
Benzine,[1]	6·50	84,126	193,215	292,442	12,942	20,725	44,091

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[1] Of this, 27,170 metre centners went to Germany in 1893, and 41,725 in 1894.

ROUMANIA.

From the results of inquiries made of the Roumanian Consul-General, it appears that there are no official records kept of the production of petroleum in that country.

The Austrian Vice-Consul at Ploesti, reports that the production of crude petroleum in Roumania for the year 1894 was as follows:—

	Tank-car loads of 100 metre centners.		Tank-car loads of 100 metre centners.
Glodeni, ...	over 900	Sarata (Buzeu), ...	600
Campina, ...	,, 800	Tega, ...	100
Doftaneti and Bustenari, . .	700 to 800	Other localities, ...	200
Ochisori and Matitza, ...	80		

HUNGARY AND BUKOWINA.

Her Majesty's Consul-General in Vienna informs the author that the total production of crude petroleum in these countries does not exceed 1,000 metre centners per annum.

ALSACE.

The production of crude petroleum in Lower Alsace in 1894 is stated to have amounted to 15,632 metric tons.

ITALY.

PRODUCTION OF PETROLEUM IN ITALY FROM 1860 TO 1891.

YEAR.	No. of mines in operation.	PRODUCTION.			No. of workmen employed.	PROVINCE.		
		Quantity.	Unit value.	Total value.		Emilia.	Chieti.	Caserta.
		Tons.	Lire.	Lire.				
1860, . .	3	5	800·00	4,000	5	5	..	..
1861, . .	5	4	800·00	3,200	8	4	..	..
1862, . .	4	4	800·00	3,200	9	4	..	..
1863, . .	7	8	800·00	6,400	18	8	..	..
1864, . .	7	10	800·00	8,000	32	10	..	..
1865, . .	10	315	209·52	66,000	70	15	300	..
1866, . .	12	138	269·86	37,240	57	20	118	..
1867, . .	11	110	349·10	38,400	58	30	80	..
1868, . .	9	51	435·29	22,200	52	21	30	..
1869, . .	8	20	800·00	16,000	45	20	..	..
1870, . .	6	12	800·00	9,600	30	12	..	..
1871, . .	6	38	263·16	10,000	40	8	..	30
1872, . .	6	46	208·69	9,600	36	6	..	40
1873, . .	5	65	172·31	11,200	35	5	..	60
1874, . .	4	84	152·38	12,800	37	4	..	80
1875, . .	3	113	138·05	15,600	38	3	..	110
1876, . .	3	402	123·38	49,600	72	2	..	400
1877, . .	2	408	132·35	54,000	45	8	..	400
1878, . .	4	602	102·99	62,000	98	2	..	600
1879, . .	4	402	124·37	50,000	70	2	..	400
1880, . .	2	283	313·05	88,595	24	53	80	150
1881, . .	2	172	445·00	76,540	24	50	58	64
1882, . .	4	183	474·55	86,844	121	44	74	65
1883, . .	5	225	259·49	58,387	92	39	125	61
1884, . .	6	397[1]	341·18	135,452	110	249	90	56
1885, . .	6	270[2]	407·65	110,066	136	112	100	57
1886, . .	7	219	416·11	91,130	145	123	50	46
1887, . .	7	208	364·04	75,720	135	158	20	30
1888. . .	5	174	319·71	55,630	75	174	..	..
1889, . .	7	177	288·13	51,000	70	177	..	..
1890, . .	9	417	289·21	120,603	177	359	35	23
1891, . .	7	100	298·91	328,800	230	1,016	60	24

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[1] This quantity of 397 tons included 2 tons (of the value of 1,000 francs) produced on the ancient property of Caruso, in the territory of Lercara (Palermo).

[2] This quantity of 270 tons included 1 ton from the property of Caruso.

JAPAN.

The production of petroleum in Japan in 1890 is shown in the following table:—

PRODUCTION OF PETROLEUM IN JAPAN IN 1890.

Province.	Prefecture.	Production.
		Gallons.
Ishikari,	Hokkaido,	1,213
Ugo,	Akita,	11,400
,,	Yamagata,	7,341
Echigo,	Niigata,	1,858,950
Shinano,	Nagano,	45,670
Totomi,	Shizkuoka,	92,542
	Total,	2,017,116

PRODUCTION OF PETROLEUM IN JAPAN FROM 1881 TO 1890.

Years.	Production.	Years.	Production.
1881,	703,217 gallons.	1886,	535,210 gallons.
1882,	814,078 ,,	1887,	350,394 ,,
1883,	859,501 ,,	1888,	1,429,971 ,,
1884,	246,647 ,,	1889,	1,960,924 ,,
1885,	290,699 ,,	1890,	2,017,116 ,,

The following are the statistics of production by the Japan Petroleum Company since its organisation in 1888:—

PRODUCTION OF PETROLEUM IN THE AMAZE FIELD, JAPAN, FROM 1888 TO 1892.

Years.	Production.	Years.	Production.
1888,	578 sho.[1]	1891,	5,077 sho.
1889,	4,522 ,,	1892 (to November),	5,920 ,,
1890,	5.228 ,,		

[1] A "sho" is about 1·8 quart.

PARAFFIN.

EXPORTS OF PARAFFIN AND PARAFFIN WAX FROM THE UNITED STATES, FROM JULY 1, 1880, TO JUNE 30, 1892.

(*Compiled from data in the United States Treasury Department.*)

Year ending 30th June.	Pounds.	Dollars.	Year ending 30th June.	Pounds.	Dollars.
1881,	5,369,821	437,187	1887,	31,546,223	2,032,713
1882,	9,121,161	579,131	1888,	36,005,522	2,168,247
1883,	14,228,551	936,885	1889,	33,826,575	2,029,602
1884,	17,089,817	1,263,197	1890,	48,516,551	2,408,709
1885,	24,378,488	1,725,344	1891,	66,366,003	3,714,649
1886,	24,289,693	1,729,313	1892,	64,998,867	3,965,263

Exports of Paraffin from the United States (in Pounds).

Countries.	1893.	1892.	1891.
Argentine Republic,	..	100	..
Austria-Hungary,	..	181,250	32,206
Belgium,	2,137,538	172,713	804,334
Brazil,	44,581	27,804	10,391
British Australasia,	314,603	292,195	89,390
British Africa,	149,291	67,218	9,633
Central American States—Costa Rica,	102,743	60,585	117,907
Guatemala,	773	..	..
China,	3,946	..	..
Colombia,	..	2,155	..
Denmark,	458,325	..	..
Dominion of Canada—N.S., N.B., &c.,	950	690	720
Quebec, Ontario, &c.,	40,412	270,870	189,685
France,	975,925	685,759	91,349
Germany,	4,898,240	6,491,864	3,676,045
Italy,	1,338,613	170,661	88,076
Japan,	1,550,081	15,841	3,217
Mexico,	964,482	854,888	794,906
Netherlands,	812,882	609,577	666,596
Peru,	..	..	11,641
Portugal,	67,004	11,643	..
Russia,	..	142,167	..
Santo Domingo,	..	..	428
Spain,	320,810	177,338	175,121
United Kingdom—England,	56,901,866	42,470,609	59,562,105
Scotland,	11,469,950	11,072,762	
Ireland,	32,877	278,088	
Uruguay,	120	..	..
Venezuela,	2,606	4,478	4,414
West Indies—British,	14,313	8,294	12,643
Danish,	120	..	..
French,	1,897	500	1,292
Hayti,	5,561	..	..
Spanish-Cuba,	38,158	14,880	4,486
Puerto Rico,	26,473	13,933	19,318
Total,	82,675,140	64,098,867	66,366,003

OZOKERITE.

Production and price of ozokerite in Galicia (Austria-Hungary).

Note.—The following figures, for the years 1877 to 1892, are from the official returns, but are considered to largely understate the production :—

Year.	Production in Metre Centners of 100 Kilos.	Year.	Production in Metre Centners of 100 Kilos.
1877,	80,610	1885,	130,258
1878,	103,420	1886,	139,254
1879,	90,666	1887,	80,500
1880,	105,270	1888,	87,800
1881,	106,491	1889,	75,600
1882,	99,300	1890,	61,699
1883,	106,290•	1891,	61,586
1884,	119,669	1892,	56,376

The author is informed that the production in 1893 amounted to 56,248 metre centners, of which 52,410 metre centners was mined in the Drohobycz District, and the remainder in Stanislaw.

The following particulars relative to the ozokerite of Boryslaw (Galicia) are taken from a report by Messrs. William Perkins and Raynar St. Stephens:—

Year.	Quantities of ozokerite sent by railway, and to the Drohobycz refineries.	Year.	Quantities of ozokerite sent by railway, and to the Drohobycz refineries.
1887, ...	13,460·70 tons.	1890, ...	11,640·25 tons.
1888, ...	13,350·00 „	1891, ...	12,490·00 „
1889, ...	12,430·35 „		

Labour employed in the industry at Boryslaw:—

2,700 men working under ground.
3,600 men working above ground.
1,800 women working ventilating fans.
450 foremen.
450 men carting, washing, picking, melting, moulding, &c.

The ozokerite produced in the Drohobycz district is all melted on the spot. In 1893 the deliveries were as follows:—

Destination.	Quantity. Metre centners.
Sosnowice (Russian Poland), ...	10,700
Germany, ...	300
Vienna, ...	9,180
Various refineries in Bohemia and Moravia (Austria), ...	25,000

From Stanislaw, 1,695 metre centners was forwarded in 1893 to Lower Austria and Bohemia. The rest was sent to Drohobycz and Boryslaw.

NATURAL GAS.

From *Mineral Resources of the United States, 1893*, by Joseph D. Weeks.

VALUE OF NATURAL GAS CONSUMED IN THE UNITED STATES, 1885 TO 1893.

Localities.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.
Pennsylvania,	4,500,000	9,000,000	13,749,500	19,282,375	11,593,989	9,551,025	7,834,016	7,376,281	6,488,000
New York, .	196,800	210,000	333,000	332,500	530,026	552,000	280,000	216,000	210,000
Ohio, . . .	100,000	400,000	1,000,000	1,500,000	5,215,669	4,684,300	3,076,325	2,136,000	1,510,000
West Virginia,	40,000	60,000	120,000	120,000	12,000	5,400	35,000	500	123,000
Indiana, . .	. .	300,000	600,000	1,320,000	2,075,702	2,302,500	3,942,500	4,716,000	5,718,000
Illinois, . .	1,200	4,000	. .	. .	10,615	6,000	6,000	12,988	14,000
Kentucky, .	. .	. .	. .	. .	2,580	30,000	38,993	43,175	68,500
Kansas, . .	. .	6,000	. .	. .	15,873	12,000	5,500	40,795	50,000
Michigan, . .	. .	12,000	. .	. .	. .	. .	. .	. .	. .
Missouri, . .	. .	. .	. .	. .	35,687	10,500	15,000	3,775	2,100
Arkansas, . .	. .	. .	. .	. .	375	6,000	250	100	100
Texas, . . .	. .	. .	. .	. .	1,728		. .	100	50
Utah, . . .	. .	. .	. .	. .	150		. .	. .	500
South Dakota,	. .	. .	. .	. .	25		. .	. .	. .
California, .	. .	. .	. .	. .	12,680	33,000	30,000	55,000	62,000
Elsewhere, .	20,000	20,000	15,000	75,000	1,900,000	1,600,000	250,000	200,000	100,000
Total, . .	4,857,200	10,012,000	15,817,500	22,629,875	21,107,099	18,792,725	15,500,084	14,800,714	14,346,250

NATURAL GAS RECORDS IN 1892 AND 1893.

	Pennsylvania.		Indiana.		Ohio.	
	1893.	1892.	1893.	1892.	1893.	1892.
Amount received for sale of gas, or value of gas consumed, . .	$3,641,095	$4,077,799	$1,052,818	$964,366	$215,440	$281,510
Value of coal or wood displaced, .	$4,022,834	$4,468,254	$1,621,063	$1,622,337	$320,498	$368,290
Number of domestic fires supplied,	119,524	153,058	55,852	55,821	11,749	9,270
Number of iron and steel works supplied, ...	33	31	1	3	..	1
Number of glass works supplied, .	43	41	15	9	..	2
Number of other establishments supplied, ...	223	252	226	244	65	88
Total number of establishments supplied, ...	299	324	242	256	65	91
Total number of wells producing, January 1, ...	805	748	411	323	166	166
Total number of producing wells drilled, ...	157	160	114	75	50	27
Total number of wells producing, December 31, ...	841	806	498	380	207	173
Total number of feet of pipe laid,	11,989,657	11,858,605	5,720,373	5,317,103	1,404,098	648,622
Total number of establishments reporting, ...	53	53	116	116	49	49

ASPHALT.

100,039 tons of solid bitumen was shipped from the Pitch Lake, Trinidad, during the year 1894.

SHALE OIL.

Statistics of the production of oil shale and shale oil will be found in Section VII.

APPEN

TANK STEAMERS AND TANK SAILING VESSELS

NAME.	Register.		Dimensions.				Cylinders.			Stroke.	Pressure.
	Gross.	Net.	Length.	Breadth.	Depth.	Moulded Depth.	H.P.	M.P.	L.P.		
"Mineral," s.s., late "Charles Howard,"	1304	849	249 0	30 1	16 9	23 4	27½	..	49½	40	65
"Amelia G. Ireland," s., . .	285	270	124 0	30 0	12 4	..	..	..	..	..	..
"Titian," s.s., ...	1249	810	231 0	31 1	23 6	..	27	..	52	30	70
"Lindesnaes," s.s., . . .	375	266	152 1	21 5	15 0	..	17½	..	28	24	..
"Mihael," s., ...	..	242	90 2	24 9	21 0	..	..	..	..	..	..
"Petriana," s.s., . . .	1672	1086	260 5	34 2	21 7	23 0	33	..	62	42	80
"Vindobala," s.s., . . .	1865	1167	261 0	34 3	21 8	23 0	33	..	62	42	80
"Einar," s., ...	653	625	154 3	30 3	19 1	..	..	..	..	..	..
"Rolf," s., ...	1254	1211	200 10	36 5	22 10	..	..	..	..	..	..
"Raleigh," s.s., oil in D. B. and A. P. T.,	1349	835	244 4	34 1	15 2	17 8	30	..	55	36	80
"Fergusons," s.s., oil in tanks,	1504	973	250 0	34 5	18 8	..	30	..	57	36	90
"Valeria," s.s., ...	247	152	120 4	23 2	9 7	10 5	10	15	24	18	160
"Robert Dickenson," s.s., .	2100	1331	278 7	35 4	22 5	23 6	36	..	68	42	80
"Chigwell," s.s., ...	1824	1192	258 8	36 2	18 7	20 0	33	..	61	33	80
"Atland," s.s., late "Marquis Scicluna,"	1599	1024	260 0	36 2	18 6	19 8	32	..	62	40	80
"Sviet," s.s., ...	1827	1474	273 9	35 1	21 5	..	36	40	66	..	80
"Gluckauf," s.s., . . .	2307	1687	300 5	37 2	23 2	23 0	22	35	58	36	150
"Bakuin," s.s., ...	1669	1093	260 4	36 0	17 5	20 4	21	35	57	39	150
"Hafis," s.s., ...	2116	1588	270 0	36 0	1 7	..	20	32	53	36	..
"Looch," s.s., ...	1446	913	255 5	34 2	17 9	19 0	20	32	53	36	150
"Vorwarts," s.s., . . .	2466	1766	298 9	36 2	23 9	..	22	35	58	39	..
"Pollux," s.s., ...	1433	918	245 0	36 0	18 5	19 8	20	30	50	36	165
"Minister Maybach," s.s., .	2881	2132	285 0	40 2	23 1	..	22	35	58	39	151
"Oural," s.s., late "Hans and Kurt,"	2422	1634	270 0	39 0	21 2	..	20½	34	55	36	..
"Willkommen," s.s., . .	3136	2430	315 0	41 2	23 8	24 6	30	37	72	48	100
"Apscheron," s.s., late "Era,"	1851	1195	271 0	37 2	15 2	16 9	21	34	57	39	154
"Hainaut," s., ...	1783	1659	248 8	40 3	22 2	..	..	..	..	..	..
"Ludwig Nobel," s.s., . .	967	744	191 7	29 4	19 5	..	26	..	50	27	..
"Paula," s.s., ...	2675	2160	285 0	40 2	30 4	..	22	35	58	39	..
"Ocean," s.s., ...	2835	1872	310 7	39 1	25 2	26 2	22	36	58	42	160
"Chester," s.s., ...	2834	1872	311 7	39 2	25 0	26 2	22	36	58	42	160
"Caucase," s.s., ...	1666	1087	250 0	35 1	24 3	..	18½	30	48	33	150
"Caroline Robt. de Massy," s.s.,	1742	1130	256 3	37 0	17 9	19 2	20	33	54	36	160

DIX B.

EMPLOYED IN THE EXPORT OF PETROLEUM.

Builders.	Date.	Place.	Owners.	Port.	REMARKS.
W. Pile,	11/1866 Rebuilt 1888.	Sunderland,	A. Suart,	London.	
.. ..	1866	Maryland,	J. F. Freeman,	New York.	
Iliff Mormsly & Co.,	2/1870	Sunderland,	P. T. and S. Co., Ld. (A. Suart),	London.	
Norddeutsche Schiffswerft,	1872	Kiel,	Aktieselskabet Lindesnaes (J. Munich & Co.),	Christiania.	
.. ..	1872	Syra,	Stefan Panargottis,	Syra.	
A. Leslie & Co.,	10/1879	Newcastle,	P. T. and S. Co., Ld. (A. Suart),	London.	
,, ,,	12/1879	,,	,, ,,	,,	
E. Burchard & Co.,	1876 Rebuilt 1886.	Rostock,	G. C. Hanson,	Tonsberg.	
A. Dekke,	1876 Rebuilt 1885.	Bergen,	,,	,,	
Caird & Purdie,	8/1881	Barrow,	J. Wood & Co.,	W. Hartlepool.	
Bertram Haswell & Co.,	10/1880	Sunderland,	J. M. Lennard & Sons,	Middlesbro',	Explosion 12/1889. Total loss.
C. Keill & Sons,	11/1881	Bristol,	J. R. D. La Parra,	Santandar.	
A. Leslie & Co.,	4/1881	Newcastle,	P. T. and S. Co., Ld. (A. Suart),	London.	
Bertram Haswell & Co.,	10/1883	Sunderland,	A. Suart,	,,	
Sunderland Shipbuilding Co.,	12/1883	,,	A. Broström,	Gothenburg.	
Motala Co.,	1885	Gothenburg,	Russian S. N. and T. Co.,	Odessa.	
Armstrong, Mitchell & Co.,	1886	Newcastle,	Deutsch - Amerikanische Petroleum Gesellschaft,	Geestemunde,	Went ashore, Fire Island. Sold for $850.
W. Gray & Co.,	6/1886	Hartlepool,	P. T.' and S. Co., Ld. (A. Suart),	London.	
Hawthorne, Leslie & Co.,	12/1886	Newcastle,	Deutsch - Amerikanische Petroleum Gesellschaft,	Hamburg.	
,, ,,	10/1886	,,	Russian S. N. and T. Co.,	Odessa.	
Armstrong, Mitchell & Co.,	1886	,,	C. Wedekind & Co.,	Geestemunde,	Lost at sea 7/1890.
Pearce Bros.,	9/1887	Dundee,	W. S. Croudace,	Dundee,	Abandoned 12/1890.
Armstrong, Mitchell & Co.,	1887	Newcastle,	Deutsch - Amerikanische Petroleum Gesellschaft,	Geestemunde.	
,, ,,	1887	,,	Soc. Anonyme p. l'Importation des Huiles de graissage,	Antwerp.	
,, ,,	5/1887	,,	Deutsch - Amerikanische Petroleum Gesellschaft,	Hamburg.	
Palmers Shipbuilding Co., Ld.,	1/1887	,,	Soc. Anonyme p. l'Importation des Huiles de graissage,	Antwerp.	
Barrow Shipbuilding Co.,	1887	Barrow,	American Pet. Co.,	Rotterdam.	
Motala Co.,	1888	Gothenburg,	Nobel Bros.,	Libau.	
Armstrong, Mitchell & Co.,	1888	Newcastle,	Deutsch.-Am. P. Gesell.,	Hamburg.	
Russell & Co.,	2/1888	Greenock,	American Pet. Co.,	Rotterdam.	
,, ,,	2/1888	,,	,, ,,	,,	
Armstrong, Mitchell Co.,	1888	Newcastle,	L. Lambert,	Antwerp.	
R. Craggs & Sons,	9/1888	Middlesbro',	R. Craggs & Sons,	Stockton,	Lost by collision 1/1891.

TANK STEAMERS AND TANK SAILING VESSELS

NAME.	Register.		Dimensions.				Cylinders.			Stroke.	Pressure,
	Gross.	Net.	Length.	Breadth.	Depth.	Moulded Depth.	H.P.	M.P.	L.P.		
"Gut Heil," s.s., ...	2552	1875	310 0	40 2	28 2	..	23	37	60	39	..
"La Hesbaye," s.s., late "Ovelgenne,"	2539	1987	300 0	39 2	28 1	..	21½	35	57	38	..
"Broadmayne," s.s., late "Oka,"	3095	1995	334 4	44 0	16 9	18 9	26	43	69	45	150
"Elbruz," s.s., . - . . .	2715	2101	309 5	40 4	28 2	..	23	37	60	39	160
"Charlois," s.s., . . .	2744	2116	310 3	39 2	25 2	26 6	22	36	58	42	160
"Kasbek," s.s., ...	2707	2098	310 0	40 4	28 3	..	23	37	60	39	..
"Lux," s.s., ...	1635	1255	250 0	35 1	24 1	..	18½	30	48	33	..
"Sophie," s.s., ...	1671	1114	235 0	33 2	23 0	..	17½	28	46	30	..
"Russian Prince," s.s., . .	2716	2102	310 0	40 4	28 3	..	23	37	60	39	..
"La Flandre," s.s., . . .	1979	1510	270 0	37 7	25 9	..	20	34	55	36	..
"Energie," s.s., . . .	2910	1908	310 0	40 1	29 5	..	23	37	60	39	150
"Standard," s.s., . . .	832	590	160 0	30 0	14 4	..	14	22	36	24	..
"Ville de Dieppe," s., . . .	..	1228	217 2	36 4	21 0	..	..	..	..	..	..
"Darial," s.s., ...	2767	1814	310 0	40 2	28 3	..	23	37	60	39	..
"Rock Light," s.s., . . .	3225	2119	312 0	40 4	21 1	22 6	22½	37	61	39	165
"Lumen," s.s., ...	2357	1554	294 0	37 7	26 6	27 9	21	35	57	36	..
"Phosphor," s.s., . . .	2023	1326	270 0	37 7	25 9	..	20	34	55	36	..
"Astral," s.s., ...	2249	1465	281 0	38 2	18 3	19 6	21	34	57	39	160
"Circassian Prince," s.s., . .	2243	1468	272 0	38 1	26 1	27 3	20½	33½	55	36	..
"Attila," s.s., ...	2141	1404	280 0	37 5	18 0	19 11	21	34	57	39	160
"Tancarville," s.s., . . .	2336	1541	292 5	37 2	18 4	19 8	22	35	58	42	160
"Wild Flower, s.s., . . .	2657	1745	300 0	40 2	18 8	20 1	24	39	64	42	150
"Prudentia," s.s., . . .	2730	1791	312 0	40 2	19 8	21 2	24	38	62	42	150
"Bayonne," s.s., . . .	3294	2154	330 0	42 2	21 1	22 2	24	40	63	48	160
"Manhattan," s.s., . . .	3300	2153	330 0	42 2	21 2	22 3	26½	42	70	45	160
"Kura," s.s., ...	2372	1558	294 0	37 7	20 2	21 3	22½	36½	60	39	160
"Rion," s.s., ...	2186	1419	279 0	37 7	19 1	20 4	22	35	58	39	150
"Burgermeister Petersen," s.s.,	2794	2090	310 0	40 2	28 3	..	23	37	60	39	..
"Elise Marie," s.s., . . .	3568	2587	320 0	42 0	29 5	..	23	37	60	42	..
"Oranje Prince," s.s., . .	1868	1214	260 0	36 0	25 7	..	19	31	51	36	..
"Petrolea," s.s., . . .	2331	1516	292 5	37 1	18 5	19 8	21	34	56	42	150
"La Campine," s.s., . . .	2542	2007	309 7	39 0	26 3	..	22	35	58	42	..
"Bremerhaven," s.s., . .	3393	2179	339 6	42 6	26 1	27 5	25	40	66	42	160
"Ville de Douai," s.s., . .	1723	1119	265 0	37 0	23 4	..	20	33	53	36	..
"Blesk," s.s., . . .	2868	2076	316 9	40 0	26 7	..	24	39	64	42	..
"Beacon Light," s.s., .	2763	2107	311 0	40 2	28 2	..	23	37	60	39	..
"Bear Creek," s.s., . . .	2411	1573	294 0	37 7	26 6	..	22	36	59	39	..
"Prudence," s.s., . . .	2319	1515	292 3	37 0	18 5	19 8	22	35	57	39	160

EMPLOYED IN THE EXPORT OF PETROLEUM—*Continued.*

Builders.	Date.	Place.	Owners.	Port.	REMARKS.
Armstrong, Mitchell & Co.,	1888	Newcastle,	Deutsch - Amerikanische Petroleum Gesellschaft,	Geestemunde.	
Armstrong, Mitchell & Co.,	1888	,,	American Pet. Co.,	Rotterdam.	
Palmers Shipbuilding Co., Ld.,	11/1888	,,	Pet. Shipping Co. of London, Ld. (A. Suart),	London.	
Armstrong, Mitchell & Co.,	1888	,,	"Elbruz" S.S. Co., Ld.,	,,	
Russell & Co.,	12/1888	Greenock,	American Pet. Co.,	Rotterdam.	
Armstrong, Mitchell & Co.,	1888	Newcastle,	"Kasbek" S.S. Co., Ld.,	London.	
,, ,,	1888	,,	W. Dickenson & Co.,	,,	Lost off coast of Greece 11/1891.
,, ,,	1888	,,	C. Wedekind & Co.,	Geestemunde.	
,, ,,	1888	,,	Jas. Knott,	Newcastle.	
,, ,,	7/1888	,,	American Pet. Co.,	Rotterdam.	
,, ,,	1888	,,	Deutsch - Amerikanische Petroleum Gesellschaft,	Geestemunde.	
J. Roach & Sons,	1888	Chester, Pa.,	Standard Oil Co.,	New York,	Converted into tank barge.
Oswald, Mordaunt & Co.,	1888	Southampton,	L. Robbe fils,	Dieppe.	
Armstrong, Mitchell & Co.,	1888	Newcastle,	"Darial" S.S. Co., Ld.,	London.	
Oswald, Mordaunt & Co.,	4/1889	Southampton,	"Rock Light" S.S. Co., Ld. (G. Croshaw and Lane & Co.),	,,	
Armstrong, Mitchell & Co.,	1889	Newcastle,	"Lumen" S.S. Co., Ld. (H. E. Moss & Co.),	Liverpool.	
,, ,,	1889	,,	"Phosphor" S.S. Co., Ld. (R. Stewart & Co.),	,,	
Palmers Shipbuilding Co., Ld.,	5/1889	,,	"Astral" S.S. Co., Ld. (W. Tapscott & Co.),	,,	
C. S. Swan & Hunter,	1889	,,	J. Knott,	Newcastle.	
R. Craggs & Sons,	8/1889	Middlesbro',	J. M. Lennard & Sons,	Middlesbro'.	
Craig, Taylor & Co.,	7/1889	Stockton,	S.S. "Tancarville," Ld. (A. Suart),	London.	
R. Thompson & Sons,	3/1889	Sunderland,	S.S. "Wild Flower," Ld. (A Suart),	,,	
Palmers Shipbuilding Co., Ld.,	7/1889	Newcastle,	S.S. "Prudentia," Ld. (A. Suart),	,,	
A. & J. Inglis,	8/1889	Glasgow,	"Bayonne" S.S. Co., Ld.	,,	
D. J. Dunlop & Co.,	9/1889	Port-Glasgow,	"Manhattan" S.S. Co., Ld.,	,,	
Armstrong, Mitchell & Co.,	8/1889	Newcastle,	"Kura" S.S. Co., Ld. (Stephens & Mawson),	Newcastle.	
Palmers Shipbuilding Co., Ld.,	8/1889	,,	"Rion" S.S. Co., Ld. (Stephens & Mawson),	,,	
Armstrong, Mitchell & Co.,	1889	,,	Deutsch - Amerikanische Petroleum Ges.,	Hamburg.	
,, ,,	1889	,,	,, ,,	,,	
,, ,,	1889	,,	J. Knott,	Newcastle.	
Craig, Taylor & Co.,	1/1890	Stockton,	Petroleum T. and Storage Co., Ld. (A. Suart),	London,	Lost by explosion 6/1892.
Palmers Shipbuilding Co., Ld.,	1890	Jarrow,	American Petroleum Co.,	Rotterdam.	
Russell & Co.,	3/1890	Greenock,	,, ,,	,,	
Armstrong, Mitchell & Co.,	1890	Newcastle,	P. Paix & Co.,	Calais.	
Motala Co.,	1890	Gothenburg,	Russian S. N. and T. Co.,	Odessa.	
Armstrong, Mitchell & Co.,	1890	Newcastle,	R. Stewart & Co.,	Liverpool.	
,, ,,	1890	,,	Bear Creek Oil & Sg. Co. (C. T. Bowring & Co.),	,,	Abandoned in mid ocean 26/12/92.
Craig, Taylor & Co.,	4/1890	Stockton,	A. Suart,	London,	Lost 1/1892 (stranded).

TANK STEAMERS AND TANK SAILING VESSELS

NAME.	Register.		Dimensions.				Cylinders.			Stroke.	Pressure.
	Gross.	Net.	Length.	Breadth.	Depth.	Moulded Depth.	H.P.	M.P.	L.P.		
"Allegheny," s.s., . . .	2914	1911	320 0	42 2	19 2	20 4	25	40	66	45	150
"Helgoland," s.s., . . .	2397	1563	294 0	37 6	26 5	..	21	35	57	36	..
"Brilliant," s.s., . . .	3162	2411	319 2	42 0	29 5	..	23	37	60	48	..
"Geestemunde," s.s., . .	2750	2101	310 0	40 2	28 2	..	23	37	60	39	..
"Standard," s.s., . . .	2765	2110	310 0	40 2	28 3	..	23	37	60	39	..
"Maverick," s.s., . . .	1722	1289	239 9	36 0	17 8	..	19	30	50	36	..
"Christine," s.s., . . .	2293	1458	280 9	27 3	18 5	..	22	35	57	39	..
"Ems," s.s., ...	423	260	149 0	27 4	11 5	..	13	21	34	27	..
"Aral," s.s., ...	2826	2160	310 0	40 2	28 2	..	22	35	58	42	..
"Weehawken," s.s., . . .	2784	2101	310 0	40 2	28 2	..	22	35	58	42	..
"Azov," s.s., ...	2332	1512	285 0	38 5	25 9	..	22	36	59	39	..
"Murex," s.s., ...	3564	2329	338 0	43 0	26 4	28 0	25½	40½	67	45	160
"Le Progrés," s.s., . . .	449	205	163 0	26 8	13 3	..	16	4 cylrs	30	18	..
"Diamant," s.s., . . .	3525	2270	330 0	43 0	29 9	..	24	40	64	48	160
"Lucerna," s.s., . . .	3242	2072	330 0	42 6	28 5	..	24	40	65	42	160
"Mannheim," s.s., . . .	3507	2257	330 0	43 0	29 9	..	24	40	64	48	160
"Astrakhan," s.s., . . .	3438	2236	330 0	42 9	28 7	..	24	40	64	42	160
"El Gallo," s.s., . . .	632	362	170 5	28 0	14 5	..	16·5	26	43	27	160
"Unionen," barque, . . .	1730	1631	248 8	40 3	22 2	..	..	..	..	..	..
"Cadagua," s.s., . . .	2394	1858	295 0	39 0	25 4	..	22½	36	59	39	160
"L'Oriflamme," s.s., . .	3328	2129	332 0	42 2	18 8	20 4	25	40	66	45	150
"Etelka," s.s., ...	2373	1524	289 0	37 4	19 6	20 7	22	36	59	39	160
"Patagonia," barque, . .	1237	1203	191 9	38 4	22 5	..	..	..	..	..	..
"Turbo," s.s., ...	4134	2659	347 5	45 7	27 3	28 6	26	42½	69	45	160
"American," s.s., . . .	3897	2927	345 4	44 1	27 6	29 2	27	44	72	48	160
"Conch," s.s., ...	3555	2314	338 4	43 0	26 4	28 0	25½	40½	67	45	160
"Henri Reith," s.s., . .	2265	1488	280 0	38 5	18 0	19 3	21½	36	59	39	160
"Cuidad de Rens," s.s., . .	1899	1210	260 0	36 2	17 0	18 0	20	33	54	36	160
"Baku Standard," s.s., . .	3708	2375	330 6	43 0	23 0	24 2	24	40	64	48	160
"Northern Light," s.s., . .	3893	2552	347 4	45 6	27 2	28 6	26	42½	69	45	160
"Clam," s.s., ...	3552	2311	338 0	43 0	26 4	28 0	25½	40½	67	45	160
"Trocas," s.s., ...	4129	2657	347 5	45 7	27 3	28 6	26	42½	69	45	160
"Luciline," s.s., . . .	3319	2132	332 0	42 2	18 8	20 4	25	40	66	45	150
"James Brand," s.s., . .	3907	2512	340 0	44 1	23 0	24 2	25	41	67	48	160
"Aras," s.s., ...	3350	2400	325 0	42 5	28 5	..	24	40	64	42	..
"Spondilus," s.s., . . .	4129	2658	347 5	45 7	27 3	28 6	26	42½	69	45	160
"Lion" (Le), s.s., . . .	2407	1559	283 3	39 9	26 2	..	23½	35½	55	47½	..
"Elax," s.s., ...	4015	2612	347 2	45 6	26 7	28 6	26	42	70	45	160
"Delaware," s.s., . . .	3855	2469	345 0	44 3	23 0	24 3	27	43½	70	51	160
"La Biguesa," barque, . .	..	.	..	..	..	..	..	..	..	..	..

EMPLOYED IN THE EXPORT OF PETROLEUM—*Continued.*

Builders.	Date.	Place.	Owners.	Port.	REMARKS.
Craig, Taylor & Co.,	8/1890	Stockton,	S.S. "Allegheny," Ld. (A. Suart),	London,	Sunk in Delaware 1/10/94.
Armstrong, Mitchell & Co.,	1890	Newcastle,	Deutsch - Amerikanische Petroleum Gesellschaft,	Geestemunde.	
" "	1890	"	" "	"	
" "	1890	"	" "	"	
" "	1890	"	" "	"	
Columbian I. Wr. Dry Dock Co.,	5/1890	Baltimore,	Standard Oil Co.,	New York.	
Burmeister & Waine,	1890	Copenhagen,	Danske Petroleums Aktieselskab,	Aarhus.	
Armstrong, Mitchell & Co.,	1890	Newcastle,	W. Keswick,	London.	
" "	1891	"	"Aral" S.S. Co., Ld. (W. Tapscott & Co.),	Liverpool.	
" "	1891	"	"Weehawken" S.S. Co., Ld.,	London.	
" "	1892	"	"Azov" S.S. Co., Ld.,	Liverpool.	
W. Gray & Co.,	7/1892	W. Hartlepool,	M. Samuel & Co.,	London.	
Armstrong, Mitchell & Co.,	1892	Newcastle,	Cie. Universelle du Canal Maritime de Suez,	Port Said.	
" "	6/1892	"	Deutsch - Amerikanische Petroleum Gesellschaft,	Hamburg.	
" "	7/1892	"	"Lucerna" S.S. Co., Ld., (H. E. Moss & Co.),	Liverpool.	
" "	7/1892	"	Deutsch - Amerikanische Petroleum Gesellschaft,	Hamburg.	
Palmers Shipbuilding Co., Ld.,	7/1892	Jarrow,	"Astrakhan" S.S. Co., Ld. (W. Tapscott & Co.),	Liverpool.	
Armstrong, Mitchell & Co.,	8/1892	Newcastle,	G. Rois de la Parra, en liquidacion,	Santander.	
Naval Construction Co.,	9/1892	Barrow,	Vestlandske Pet. Co.,	Bergen.	
Armstrong, Mitchell & Co.,	9/1892	Newcastle,	Fourcade y Gurtubay,	Bilbao.	
Craig, Taylor & Co.,	9/1892	Stockton,	A Suart & Co.,	London.	
Armstrong, Mitchell & Co.,	9/1892	Newcastle,	Mineralöl Raffinerie Actien Gesellschaft,	Fiumé.	
T. Killam,	1880 Rebuilt 1892.	Tuskel, N.S.,	G. C. Hansen,	Christiania.	
J. Laing,	11/1892	Sunderland,	M. Samuel & Co.,	London.	
Palmers Shipbuilding and Iron Co., Ld.,	10/1892	Jarrow,	American Pet. Co.,	Rotterdam.	
W. Gray & Co., Ld.,	12/1892	W. Hartlepool,	M. Samuel & Co.,	London.	
R. Craggs & Sons,	11/1892	Middlesbro',	J. M. Lennard & Sons,	Middlesbro'.	
Grangemouth Dock Yd. Co.,	12/1892	Grangemouth,	Sociedad la Mutua,	Barcelona.	
Armstrong, Mitchell & Co.,	12/1892	Newcastle,	Anapa Co., Ld. (A. Suart, manager),	London.	
Naval Constr. and Arm. Co.,	1/1893	Barrow,	"Northern Light" S.S. Co. (G. Croshaw and Lane & Co.),	"	
W. Gray & Co., Ld.,	1/1893	W. Hartlepool,	M. Samuel & Co.,	"	
James Laing,	1/1893	Sunderland,	" "	"	
Craig, Taylor & Co.,	3/1893	Stockton,	Pet. Shipp. Co. of London, Ld. (A. Suart),	"	
Armstrong, Mitchell & Co.,	3/1893	Newcastle-on-Tyne,	A. Suart & Co.,	"	
Palmers Shipbuilding and Iron Co., Ld.,	4/1893	Jarrow,	"Aras" S.S. Co., Ld. (Stephens & Mawson),	Newcastle.	
James Laing.	4/1893	Sunderland,	M. Samuel & Co.,	London.	
Société des Forges et Chantiers, Seine Inférieure,	1893	Havre,	Deutsch et Cie.,	Havre.	
W. Gray & Co., Ltd.,	4/1893	W. Hartlepool,	M. Samuel & Co.,	London.	
D. J. Dunlop & Co.,	5/1893	Port-Glasgow,	"Delaware" S.S. Co., Ld.,	"	
Grangemouth Dock Yd. Co.,	5/1893	Grangemouth,	Babe & Co.,	Vigo, Spain.	

Tank Steamers and Tank Sailing Vessels

Name.	Register.		Dimensions.				Cylinders.			Stroke.	Pressure.
	Gross.	Net.	Length	Breadth.	Depth.	Moulded Depth.	H.P.	M.P.	L.P.		
"Suram," s.s., ...	3029	2335	325 0	42 6	21 2	22 3	24	40	64	42	160
"Erivan," s.s., ...	2424	1506	265 0	38 6	25 8	..	22	36½	60	42	..
"Lucigen," s.s., ...	3416	2183	330 0	42 7	28 4	..	24	40	64	48	..
"Volute," s.s., ...	4006	2599	347 0	45 6	26 7	28 6	26	42	70	45	..
"Batoum," s.s., ...	4054	2621	345 0	44 7	29 0	23 3	26	42	68	45	..
"Potomac," s.s., ...	3868	2472	345 2	44 2	23 0	24 3	27½	45	70	54	..
"Mexican Prince," s.s., . .	3028	1953	328 0	41 0	26 3	..	23	28	62½	42	..
"San Ignacio de Loyola," s.s., .	674	621	180 0	31 0	15 10½	..	..	.	..	..	..
"St. Helens," s.s., ...	4007	2588	345 0	45 2	21 7	23 0	26	42	68	45	..
"Bullmouth," s.s., ...	4018	2607	347 0	45 6	26 7	28 6	26	42	70	45	160
"Georgian Prince," s.s., . .	3245	2083	328 0	42 0	20 1	21 0	24	40	65	42	160
"Lackawanna," s.s., . . .	3855	2468	345 0	44 3	23 0	24 3	27	43½	70	51	160
"Hotham Newton," s.s., . .	2661	1713	310 0	41 0	18 3	19 6	24	39	64	42	160
"Vedra," s.s., ...	4057	2622	345 0	44 7	22 0	23 3	26	42½	69	48	160
"Snowflake," s.s., ...	2710	1726	294 0	39 6	19 8	20 10	23	37	60	42	160
"Duffield," s.s., ...	3767	2456	340 0	44 2	22 1	23 4	25½	41	68	48	160
"Mexicano," s.s., ...	1973	1264	270 0	38 2	22 6	..	21	35	57	39	..
"Euplectela," s.s., ...	3918	2507	340 0	44 0	22 9	24 2	25	41	67	48	160
"Deutschland," s.s., . . .	3796	2542	338 0	43 8	..	..	23¾	40	64⅕	49⅕	..
"Pouschkin," s.s., ...	1043	852	246 0	27 7	18 5	..	20⅝	2 cylrs	38	23⅝	..
"Vorotan," s.s., ...	543	369	150 5	28 0	13 7	..	22	2 cylrs	42	24	..
"Alla Verdi," s.s., ...	994	676	252 5	27 8	17 1	..	14	22	36	27	..
"Marmedshakh," s.s., . . .	..	..	..	..	..	..	..	..	..	.	..
"Amasie," s.s., ...	543	369	150 3	28 0	13 7	..	22	2 cylrs	42	24	..
"August Korff," s.s., . . .	4131	3104	352 1	45 2	22 1	.	25 9/16	40⅛	67	45¼	..
"Pascha Dadascheff," s.s., .	1054	865	246 0	27 7	17 3	..	20⅝	4 cylrs twin screw.	38	23⅝	..
"Excelsior," s.s., ...	3796	2540	338 0	43 7	31 8	..	24	40	64	49	..
"Washington," s.s., ...	4408	2903	353 0	45 0	31 5	..	24	40	64	49	..
"Sabine Rickmers," s.s., . .	1026	690	201 1	27 9	20 0	..	17⅝	28	44½	27⅝	..
"Chesapeake," s.s., ...	4557	2925	370 0	47 1	27 8	29 3	27	43½	70	51	160
"Rotterdam," s.s., ...	4273	2784	360 0	46 5	27 8	29 3	28½	46	75	48	..
"Pectan," s.s., ...	4778	3123	375 6	48 0	29 8	31 6	27½	43½	73	48	160
"Auréole," s.s., ...	3975	2553	345 0	47 2	21 9	23 9	27	44	71	48	160
"Nerite," s.s., ...	..	..	375 6	48 0	29 8	31 6	27½	43½	73	48	160
"Telena," s.s., ...	..	..	388 0	48 0	29 8	31 6	27½	43½	73	48	160
"Czar-Nicolai II.," s.s., . .	2104	1317	267 5	37 11	24 9	..	19	27	39 & 67	35	..
"Le Coq," s.s., ...	3390	2169	330 0	42 7	28 4	..	24	40	64	48	160
"Cowrie," s.s., ...	..	..	375 6	48 0	29 8	31 6	27½	43½	73	48	160

Employed in the Export of Petroleum—*Continued.*

Builders.	Date.	Place.	Owners	Port.	Remarks.
James Laing,	1893	Sunderland,	"Suram" S.S. Co., Ld., (Stephens & Mawson),	Newcastle.	
Palmers Shipbuilding and Iron Co., Ld.,	6/1893	Jarrow,	Soc. An. pour l'imp. des Huiles de Graissage,	Antwerp.	
Armstrong, Mitchell & Co.,	6/1893	Newcastle-on-Tyne,	"Lucigen" S.S. Co., Ld. (H. E. Moss & Co.),	Liverpool.	
W. Gray & Co.,	6/1893	W. Hartlepool,	M. Samuel & Co.,	London.	
James Laing,	6/1893	Sunderland,	"Batoum" S. S. Co., (A. Suart),	,,	
A. & J. Inglis,	7/1893	Glasgow,	"Potomac" S.S. Co., Ld.,	,,	
C. S. Swan & Hunter,	7/1893	Wallsend-on-Tyne,	James Knott,	Newcastle.	
Craig, Taylor & Co.,	7/1893	Thornaby-on-Tees,	L. Mercader & Vda de Londais,	San Sebastian.	
,, ,,	1893	Stockton,	Pet. Sh. Co. of London, Ld. (A. Suart),	London.	
W. Gray & Co., Ld.,	1893	W. Hartlepool,	M. Samuel & Co.,	,,	
Armstrong, Mitchell & Co.,	9/1893	Newcastle,	James Knott,	Newcastle.	
D. J. Dunlop & Co.,	10/1893	Port-Glasgow,	"Lackawanna" S.S. Co., Ld.,	London.	
Raylton Dixon & Co.,	10/1893	Middlesbro',	J. M. Lennard & Sons,	Middlesbro'.	
J. Laing,	10/1893	Sunderland,	Pet. Sh. Co. of London, Ld. (A. Suart),	London.	
Armstrong, Mitchell & Co.,	1893	Newcastle,	Bear Creek Oil and Shipping Co. (C. T. Bowring & Co., Managers),	,,	
Tyne I.S.B. Co., Ld.,	12/1893	,,	Northern Pet. Tank S.S. Co., Ld. (Hunting & Son, Managers),	Newcastle.	
Craggs, Sons & Co.,	1893	Middlesbro',	Waters Pierce Oil Co.,	St. Louis.	
Armstrong, Mitchell & Co.,	1/1894	Newcastle,	M. Samuel & Co.,	London.	
Stettiner Maschinenb. Act. Ges. "Vulcan,"	1893	Bredow a/O.,	Deutsch-Amerikanische Petroleum Ges.,	Hamburg.	
Kockums Utck. Verk. Akt.,	..	Malmo,	M. M. Berne & Co.,	Baku.	
W. Dobson & Co.,	1894	Newcastle,	Pogosoff & Co.,	,,	
,, ,,	1894	,,	Manafor,	Astrakhan.	
Armstrong, Mitchell & Co.,	1894	,,	.. ..	..	
W. Dobson & Co.,	1894	,,	Armenian S.S. Co.,	Baku.	
J. C. Tecklenborg,	1894	Geestemunde,	Deutsch-Amerikanische Petroleum Ges.,	Hamburg.	
Kockums Mekaniska Verkstads Aktiebolog,	1894	Malmo,	A. Dadascheff,	Astrakhan.	
Act. Ges. Vulcan,	1894	Stettin,	Deutsch-Amer. Pet. Ges.,	Hamburg.	
Stettiner Masch. A. G. Vulcan,	1894	,,	,, ,,	,,	
Rickmers, R.R. & S.A.G.	1894	Geestemunde,	Rickmers Reismühlen, Rhederie & Schiffbau A. G.,	Bremerhaven.	
D. J. Dunlop & Co.,	1895	Port-Glasgow,	"Chesapeake" S.S. Co., Ld.,	London.	
Palmers Shipbuilding and Iron Co., Ld.,	6/1895	Newcastle,	American Petroleum Co.,	Rotterdam.	
W. Gray & Co., Ld.,	9/1895	W. Hartlepool,	M. Samuel & Co.,	London.	
Tyne I. S. B. Co., Ld.,	8/1895	Newcastle,	Hunting & Son,	Newcastle.	
Armstrong, Mitchell & Co., Ld.,	10/1895	,,	M. Samuel & Co.,	London.	
W. Gray & Co., Ld.,	10/1895	W. Hartlepool,	,, ,,	,,	
F. Schichaw,	9/1895	Danzig,	Mineralölwerke, Albrecht & Co.,	Hamburg.	
Armstrong, Mitchell & Co.,	8/1895	Newcastle,	H. F. Swan (Lane & Macandrew, Managers),	..	
,, ,,	..	,,	M. Samuel & Co.,	London.	

The following list of tank steamers and tank sailing vessels employed in the transport of petroleum on the Caspian Sea, has been supplied to the author by Dr. Dvorkovitch :—

TANK STEAMERS AND TANK SAILING VESSELS EMPLOYED ON THE CASPIAN.

Number of Steamers.	Number of Sailing Vessels.	Names of Steamers.	Names of Sailing Vessels.	Year of Construction.	Owners.	Capacity in Cub. Ft.	Voyages in 1892.	Total of Load during 1892. Cub. Ft.
	1	..	"Askarie,"	1877	Achund & Co.,	12,137	8	97,096
	2	..	"Ria Abad,"	,,	G. Gadjeb & Co.,	7,568	2	15,136
1	..	"Zoroastre,"	..	1878	Nobel Bros.,	15,610	39	608,790
	3	..	"Alexander,"	,,	Merkoulieve,	13,640	6	81,840
	4	..	"Arey Kegetzic,"	,,	Kerakozove,	12,033	5	60,165
	5	..	"Arshac,"	,,	Sarkizianz,	10,678	3	32,034
	6	..	"Ajastan,"	,,	Avetove & Sarkis,	10,937	7	76,559
	7	..	"Blagosloveny,"	,,	Afonasieff,	9,005	4	36,020
	8	..	"Grosa,"	,,	A. Djabrailove,	10,105	3	30,315
	9	..	"Zviesda,"	,,	Ashourove,	12,456	10	124,560
	10	..	"Nadjof Abad,"	,,	Raghimove,	9,843	6	59,058
	11	..	"Nadjof Abad,"	,,	Verdieve,	13,656	7	95,592
	12	..	"Alli,"	,,	Melikove,	9,760	5	48,800
	13	..	"St. Nicolas,"	,,	Warlamove,	13,801	8	110,408
	14	..	"Pomotchnick,"	,,	Aleshin,	11,329	7	79,303
	15	..	"Samson,"	,,	Avetove,	11,238	7	78,666
	16	.	"Soious,"	,,	Artemieve,	8,711	7	56,977
	17	..	"Trapesund,"	,,	Kussiss & Co.,	14,208	7	99,456
2	..	"Boudda,"	..	1879	Nobel Bros.,	22,050	40	882,000
	18	..	"Alexandra,'	,,	Popoff,	13,050	3	39,150
	19	..	"Araks,"	,,	Talibove,	18,050	6	108,300
	20	..	"Venera,"	,,	Tumaeve,	13,343	6	80,058
	21	..	"Dagestan,"	,,	A. Winink,	10,848	1	10,848
	22	..	"Saigham,"	,,	G. Babaieff & Co.,	9,103	5	45,515
	23	..	"Melikove,"	,,	Katcheve,	7,686	8	61,488
	24	..	"Michail,"	,,	Teheremin,	13,625	4	54,500
	25	..	"St. Nicholas,'	,,	Krasilnikove,	11,416	7	79,912
	26	..	"Opit,"	,,	Katsheeve,	16,770	1	16,770
	27	..	"Russia,"	,,	Dadash-Rsa-Kulibin,	9,921	2	19,842
	28	..	"Three Brothers,"	,,	Kolesnikove,	11,739	8	93,912
	29	..	"Chudadad,"	,,	Kiazimove,	8,371	2	16,742
	30	..	"Shushanie,"	,,	G. Aslan & K. Mamed,	11,391	8	91,128
3	..	"Kolomna,"	..	1880	Co. Droujina,	36,355	26	608,310
4	..	"Sheksna,"	..	,,	Kaspi,	22,530	27	945,230
	31	..	"Ali-Abad."	,,	A. S. Talib,	9,685	7	67,795
	32	..	"Viera,"	,,	Bourlakove,	8,697	3	26,091
5	..	"Ararat,"	..	1881	Dadasheve, G.	15,096	31	467,976
6	..	"Brama,"	..	,,	Nobel Bros.,	31,636	44	1,391,984
7	..	"Magomed,"	..	,,	,,	35,636	39	1,179,282
8	..	"Moissey,"	..	,,	,,	30,238	39	1,389,804
9	..	"Socrat,"	..	,,	,,	34,878	42	1,454,876
	33	..	"Abdul Tasil,"	,,	M. B. J. Ismael,	12,267	5	61,335
	34	..	"Armenia,"	,,	Kolesnikoff,	22,961	9	206,649
	35	..	"Assan-Abad,"	,,	Usseinove & Co.,	16,914	6	101,484
	36	..	"Djabarie,"	,,	A. K. B. Coffar,	11,415	2	22,830
	37	..	"Drujba,"	,,	A. Manafove,	17,622	6	105,732
	38	..	"Efrat,"	,,	Koulikove,	18,021	4	72,084
	39	..	"Ebraghim-Abad,"	,,	Babasheve,	7,125	5	35,625
	40	..	"Imperator,"	,,	M. Zakieve,	12,486	4	49,944
	41	..	"Konstantin,"	,,	Rachimove,	12,500	4	50,000
	42	..	"Mirvary,"	,,	M. Bagirove & Co.,	17,958	7	125,706
	43	..	"Michael,"	,,	Salin,	14,228	6	85,368
	44	..	"Nachitchivan,"	,,	Achundove,	13,861	7	97,027
10	..	"Darwin,"	..	1882	Nobel Bros.,	34,718	41	1,423,438
11	..	"Koran,"	..	,,	,,	34,808	42	1,461,936
12	..	"Kostroma,"	..	,,	Co. Drujina,	41,856	30	2,455,680
13	..	"Pirogove,"	..	,,	Nobel Bros.,	12,539	33	413,787
14	..	"Poseydon,"	..	,,	,,	23,432	22	515,504
15	..	"Spinoza,'	..	,,	,,	34,700	42	1,457,400
	45	..	"Alexander,"	,,	Sollin,	20,404	6	122,424
	46	..	"Andrey,"	,,	Bojanove,	15,047	6	90,262

TANK STEAMERS, &c.—*Continued.*

Number of Steamers.	Number of Sailing Vessels.	Names of Steamers.	Names of Sailing Vessels.	Year of Construction.	Owners.	Capacity in Cub. Ft.	Voyages in 1892.	Total of Load during 1892. Cub. Ft.
	47	..	"Astara,"	1882	Kerimove,	5,685	3	17,055
	48	..	"Bouria,"	,,	G. Djabrail,	16,863	7	118,041
	49	..	"Basili,"	,,	Karadjeve,	23,589	7	165,123
	50	..	"Goloub,"	,,	Bochkarove,	13,134	6	78,804
	51	..	"Istambul,"	,,	C. A. Marieve,	10,076	5	50,380
	52	..	"Kars,"	,,	Alieve,	11,001	3	33,003
	53	..	"Lebed,"	,,	Cochin,	23,700	7	165,900
	54	..	"Neapol,"	,,	Karaeve & Co.,	10,621	5	53,105
	55	..	"Nijegorod,"	,,	Krizkai,	12,745	5	63,725
	56	..	"Rognieda,"	,,	Bash & Vorobieve,	22,534	8	180,272
	57	..	"Rustam Abad,"	,,	Hagimove,	21,649	6	129,894
	58	..	"Sam Pasha,"	,,	G. Djevat,	8,555	3	25,665
	59	..	"Thre Sviatitel,"	,,	A. Kylieve,	23,460	5	117,300
	60	..	"Usein Abad,"	,,	Bakichanove,	4,182	2	..
	61	..	"Chamid Abad,"	,,	Rasulove & Mam,	8,806	3	26,418
	62	..	"Tahernogoria,"	,,	Chan & Bakich,	18,070	7	126,490
16	..	"Grigorian,"	..	1883	Kolesnikove,	22,504	40	900,160
17	..	"Linney,"	..	,,	Nobel Bros.	33,897	42	1,423,674
18	..	"Opit,"	..	,,	Kastahieve,	15,023	48	721,104
19	..	"Talmud,"	..	,,	Nobel Bros.,	34,758	38	1,320,804
	63	..	"Caukas,"	,,	Djab & R. Zein,	20,561	9	185,049
	64	..	"Leon,"	,,	Rasulove & Jacob,	18,948	7	132,636
	65	..	"Machmudie,"	,,	Tair Ramasanove,	21,560	6	129,360
	66	..	"Orel,"	,,	Gubin & Simeonove,	20,509	6	123,054
20	..	"Gorisont,"	..	1884	Ponisovkin,	19,746	38	750,348
21	..	"Spasatiel,"	..	,,	Buniatove,	20,774	47	976,378
	67	..	"Krestianin,"	,,	Kalmikove,	13,257	2	26,514
	68	..	"Kulibin,"	,,	,,	9,978	5	49,890
	69	..	"Towaristah,"	,,	Merkulieve,	21,242	8	169,936
22	..	"Merkuri,"	..	1885	Merkulieve Bros.,	28,489	45	1,282,005
23	..	"Nijni Novgorod,"	..	,,	Cny. Caspi,	15,569	32	498,208
	70	..	"Shipka,"	,,	Artemieve,	17,431	8	139,448
	71	..	"Rubicon,"	,,	G. Aslan,	11,798	1	11,798
	72	..	"Three Brata,"	,,	Gubunin,	8,047	5	40,235
24	..	"Constantin,"	..	1886	Tumaeve,	20,668	44	909,392
25	..	"Ost India,"	..	,,	Artemieve,	39,960	13	519,480
	73	..	"Acpari,"	,,	Achundove,	9,599	2	19,198
	74	..	,,	,,	G. Babaieve,	17,199	4	68,796
	75	..	"Alexander,"	,,	Lubaeve,	10,355	3	31,065
	76	..	"Geidar Abad,"	,,	Artakishieve,	8,480	3	25,440
	77	..	"Guri Prepodobny,"	,,	Stepanove,	15,750	3	47,250
	78	..	"Derjova,"	,,	Kolesnikove,	16,437	7	115,059
	79	..	"Medina,"	,,	K. Babasheve,	13,085	6	78,510
	80	..	"Russia,"	,,	Dorofeieve,	15,748	4	62,992
	81	..	"Sached Zaigam,"	,,	Bagirove,	27,137	6	162,882
	82	..	"Stambul,"	,,	Ibragimove,	11,129	6	66,774
26	..	"Baku,"	..	1887	Sch. Dadasheve,	21,624	36	778,464
27	..	"Minin,"	..	,,	Somin,	24,178	43	1,039,654
28	..	"Serega,"	..	,,	Tumaieve,	21,582	37	798,534
	83	..	"Afganistan,"	,,	Lobove,	8,173	2	16,346
	84	..	"Ali Abad,"	,,	Useinove & Co.,	18,167	6	109,002
	85	..	,,	,,	M. Kulieve,	15,560	6	93,360
	86	..	"Askari,"	,,	Achund & Alek,	12,137	8	97,096
	87	..	"Viera,"	,,	Kulikove,	23,738	9	23,738
	88	..	"Cronstadt,"	,,	Dmitrieve,	12,802	6	76,812
	89	..	"St. Paul,"	,,	Semienove,	18,520	4	74,080
	90	..	"Ras Abad,"	,,	A. G. Medjie,	5,132	2	10,267
	91	..	"Russ,"	,,	Solin,	18,620	6	111,720
	92	..	"Samara,"	,,	G. Dadasheve,	14,388	7	100,716
	93	..	"Sviatoslave,"	,,	N. Vesielove,	8,872	2	17,744
	94	..	"Teighun,"	,,	Djafarove,	7,971	3	23,913
	95	..	"Teimur Abad,"	,,	Kireieff,	16,544	6	99,264
	96	..	"Usseinie,"	,,	Ashurove,	23,337	4	93,348
29	..	"Abbassia,"	..	1888	A. Useinove,	21,857	40	874,280
30	..	"Admiral,"	..	,,	A. Dadasheve,	23,364	38	1,887.832
31	..	"Arshak,"	..	,,	Tumaeve,	21,274	45	957,330

TANK STEAMERS, &c.—*Continued.*

Number of Steamers.	Number of Sailing Vessels.	Names of Steamers.	Names of Sailing Vessels.	Year of Construction.	Owners.	Capacity in Cub. Ft.	Voyages in 1892.	Total of Load during 1892. Cub. Ft.
32	..	"Michael & Sons,"	..	1888	Kastsheeve,	31,328	48	1,503,744
33	..	"Persianin,"	..	,,	Dadasheve,	21,822	39	851,058
34	..	"Pojarski,"	..	,,	Peterin,	37,194	43	1,227,402
35	..	"Raphael,"	..	,,	Arafelove,	24,171	39	942,669
36	..	"S. Shibaeff,"	..	,,	Richter,	39,531	48	1,897,488
	97	..	"Abbasia,"	,,	Ashurove,	20,730	11	228,030
	98	..	"Aga,"	,,	M. A. Zerbali,	7,087	2	14,074
	99	..	"Aga Dadasheve,"	,,	A. Dadasheve,	24,265	6	145,590
	100	..	"America,"	,,	Aleskerianz,	14,485	5	72,425
	101	..	"Askarie,"	,,	A. Dadasheve,	28,401	6	170,406
	102	..	"Asman,"	,,	A. Dadasheve,	22,287	6	133,722
	103	..	"West India,"	,,	Artemieve,	48,626	11	534,886
	104	..	"Vladimir,"	,,	Varlamove,	21,018	6	126,108
	105	..	"Iskanderie,"	,,	Ashurove,	16,121	6	96,726
	106	..	,,	,,	Shukiurove,	26,180	9	235,620
	107	..	"Lbove,"	,,	Lbove,	21,712	7	151,984
	108	..	"London,"	,,	Alieve & Kulieve,	24,039	7	168,273
	109	..	"Meteor,"	,,	Skripensky,	18,686	8	149,488
	110	..	"Moscou,"	,,	Tagieve & Co.,	12,510	7	87,570
	111	..	"Orel,"	,,	K. Useinove,	9,679	4	38,716
	112	..	"Raswiet,"	,,	Beliamin,	21,545	8	172,360
	113	..	"Ras Abad,"	,,	Zeinalove,	19,494	7	136,458
	114	..	"Samara,"	,,	Seniukove,	20,644	7	144,508
	115	..	"Uragan,"	,,	Djabrail, G.,	11,098	5	55,490
	116	..	"Usein Abad,"	,,	Fatalieve,	11,473	4	45,892
	117	..	"Usein Abad,"	,,	Tafieve,	9,977	2	19,954
	118	..	"Usuf Abad,"	,,	G. Dadasheve,	8,211	5	41,055
	119	..	"Sam Aga,"	,,	S. Dadasheve,	15,642	7	109,494
37	..	"Benardakie,"	..	1889	Bouniatove,	34,480	48	1,655,040
38	..	"Vladimir,"	..	,,	Sumarokove,	37,403	40	1,496,120
39	..	"Vadkinski Zavod,"	..	,,	Grubisich,	44,987	49	2,203,963
40	..	"Lazar,"	..	,,	Tumaeve,	21,700	43	933,100
41	..	"Elbruss,"	..	,,	Caukas & Merkuri,	25,185	38	957,030
	120	..	"Abbassia,"	,,	Babasheve,	19,422	7	108,954
	121	..	"Aleksei,"	,,	Kolesnikove,	29,189	9	262,701
	122	..	"Candagar,"	,,	Useinove,	29,003	6	174,018
	123	..	"Trat,"	,,	G. Rachimove,	20,980	6	125,880
	124	..	"Irad,"	,,	Kulib & Becove,	8,703	1	8,703
	125	..	"Ispagan,"	,,	Djafarove,	26,821	8	214,568
	126	..	"Caucas,"	,,	Lbove,	29,250	8	234,000
	127	..	"Constantinopol,"	,,	Dmitrieff,	13,666	3	40,998
	128	..	"Krestian,"	,,	Kolinikove,	20,945	5	104,725
	129	..	"Melikie,"	,,	Ashurove,	29,557	6	177,342
	130	..	"Michael,"	,,	Cheremin,	13,625	4	54,500
	131	..	"Mustagin,"	,,	A. Dadasheve,	17,204	5	86,020
	132	..	"Samarkand,"	,,	Abdulaeve,	23,875	7	167,125
	133	..	"Sam Dadash,"	,,	G. Rsaieve,	14,706	5	73,530
	134	..	"Serega,"	,,	Melikove,	17,193	5	85,965
	135	..	"Daghestan,"	,,	Rachimove,	20,980	6	125,880
	136	..	"Three Saints,"	,,	Sidorkin,	25,023	6	150,138
	137	..	"Useinie,"	,,	Bachichonove,	8,712	3	26,136
	138	..	"Usuf Abad,"	,,	Achundove,	24,569	4	98,276
	139	..	"Djaragim,"	,,	A. Gulieve,	16,436	6	98,616
42	..	"Awetik,"	..	1890	Gukassove,	41,570	42	1,745,940
43	..	"Aga Dadasheve,"	..	,,	Aga Dadasheve,	21,200	48	1,017,600
44	..	"Wagam,"	..	,,	Adamove,	37,360	48	1,793,280
45	..	"Waspurakan,"	..	,,	Avetove,	27,031	42	1,135,302
46	..	"Victor Hirsh,"	..	,,	Hirsh,	47,872	46	2,202,012
47	..	"Caucas,"	..	,,	Arafelove,	41,370	40	1,654,800
48	..	"Kokkum,"	..	,,	Berne & Co.,	20,900	45	970,500
49	..	"Souleimania,"	..	,,	Useinove,	23,552	44	1,036,288
50	..	"Chamid,"	..	,,	Rasulove,	22,390	67	1,500,130
	140	..	"Alexander,"	,,	Zavialove,	33,273	9	299,457
	141	..	"Alex. Macadon,"	,,	Darofeeve,	18,065	8	144,520
	142	..	"Alli Abad,"	,,	Bakarove,	18,770	8	150,160
	143	..	"Mamed Abad,"	,,	Zeinalove,	15,606	7	109,242

TANK STEAMERS, &c.—*Continued.*

Number of Steamers.	Number of Sailing Vessels.	Names of Steamers.	Names of Sailing Vessels.	Year of Construction.	Owners.	Capacity in Cub. Ft.	Voyages in 1892.	Total of Load during 1892. Cub. Ft.
	144	..	"Mashala,"	1890	Bagirove,	17,999	6	107,994
	145	..	"Rothschild,"	,,	,,	27,005	9	203,045
	146	..	"Russki Korable,"	,,	Giitchin,	37,096	7	259,662
	147	..	"Ribak,"	,,	Worobieve,	18,290	9	164,610
51	..	"America,"	..	1891	Assadulaieve,	38,448	48	1,845,504
52	..	"Aramaiss,"	..	,,	Armenian S. S. Co.,	35,151	43	1,511,493
53	..	"Conrad Bansa,"	..	,,	Zeweke,	50,601	39	1,973,439
54	..	"Tcherni Gorod,"	..	,,	Mussa Nagieve,	38,731	46	1,781,626
55	..	"Casbeck,"	..	,,	Caukas & Mercuri,	..	38	..
56	..	"Magomedie,"	..	,,	..	22,620	48	685,760
57	..	"Undina,"	..	,,	Babasheve & Z.	16,207	32	518,624
	148	..	"Aziss,"		..	14,170	8	113,360
	149	..	"Gasham Shain,"		..	20,173	4	80,692
	150	..	"Gerrat,"		..	8,016	3	24,048
	151	..	"Abass Abad,"		G. Tagieve,	21,160	6	126,960
	152	..	,,		N. Aleskerove,	25,520	6	153,120
	153	..	"Abass Aba,"		Aleskerove.	18,900	7	131,300
	154	..	"Abass Gas,"		Tagieve & Sons,	21,562	8	172,496
	155	..	"Ajdar,"		Dadasheve,	9,309	7	65,163
	156	..	"Alli,"		Alieff,	9,800	2	19,600
	157	..	"American,"		Zainalove,	12,146	3	16,438
	158	..	"St. Anna,"		,,	..	1	..
	159	..	"Armenian,"		..	..	3	..
	160	..	"Assan Abad,"		Dadasheve,	13,886	5	69,430
	161	..	,,		Ashumove,	24,558	7	171,916
	162	..	"Askarie,"		Useinove,	17,100	4	68,400
	163	..	"Asker Abad,"		Zeinalove Bros.,	12,858	4	51,432
	164	..	"Bagdad,"		..	..	2	..
	165	..	"Bajirie,"		Aleskerove,	16,521	5	82,605
	166	..	,,		A. B. Fatalief,	7,429	2	14,848
	167	..	"Akpari,"		Babaieve,	17,199	4	66,796
	168	..	"Berlin,"		Useinove,	16,485	6	98,910
	169	..	"Basili,"		Kussiss & Co.,	16,412	6	98,472
	170	..	"Warobei,"		Z. M. Kull,	4,383	3	13,149
	171	..	"George,"		Ashurove,	15,571	3	46,713
	172	..	"Gerold,"		Skripkin & Vorobieve,	17,843	10	178,430
	173	..	"Geidarie,"		Kerim Assanove,	24,277	10	242,770
	174	..	"Geidar Abad,"		A. M. Alieve,	11,100	7	77,700
	175	..	"Goloub,"		Burak,	..	1	..
	176	..	"Derbent,"		Tagieve,	20,000	10	200,000
	177	..	"Elisabeth,"		Kireeff	14,078	5	70,390
	178	..	"Efrat,"		..	..	2	..
	179	..	,,		Redkin,	..	2	..
	180	..	,,		,,	14,195	6	85,170
	181	..	"Zargan,"		Djababarove,	11,091	6	66,546
	182	..	"Imrat,"		Ashumove,	10,801	7	75,607
	183	..	"Iskanderie,"		A. K. Badalove,	9,180	1	9,180
	184	..	"Islambul,"		Dadasheve,	16,397	7	114,779
	185	..	"John,"		Safarove,	6,889	2	13,778
	186	..	"Kolomeitseff,"		Kolomeitseff,	10,666	6	63,996
	187	..	"Constantin,"		Kitaheef,	..	5	..
	188	..	,,		..	8,146	2	16,292
	189	..	"Koroll,"		Merkulieve,	19,961	9	179,649
	190	..	"Krestianin,"		..	..	7	..
	191	..	"Krestianka,"		..	..	1	..
	192	..	"Kutuzove,"		Dorofeeve,	31,150	9	279,850
	193	..	"Kiazumie,"		Abdulaeve,	12,010	7	84,070
	194	..	,,		Ashumove,	14,350	6	86,100
	195	..	"Lazar,"		Alieve,	3,635	2	7.270
	196	..	"Lebed,"		Zaitseve,	6,572	2	13,144
	197	..	"Leve,"		Abdulaeve,	9,849	4	39,396
	198	..	"Liubove,"		Warlamove,	18,558	7	129,906
	199	..	,,		Zeinalove,	..	1	..
	200	..	"Mamed Abad,"		..	..	2	..
	201	..	,,		Dadasheve,	14,873	1	14,873
	202	..	,,		Mustafieve,	18,917	10	189,710

TANK STEAMERS, &c.—*Continued.*

Number of Steamers.	Number of Sailing Vessels.	Number of Steamers.	Names of Sailing Vessels.	Owners.	Capacity in Cub. Ft.	Voyages in 1892.	Total of Load during 1892. Cub. Ft.
	203	..	"Margelan,"	..	..	4	..
	204	..	"Macmudie,"	Ramasanove,	11,097	4	44,388
	205	..	"Minerva,"	Kussiss,	13,451	5	67,255
	206	..	"Minin,"	..	..	3	..
	207	..	"Michael,"	Ermoloeve,	..	6	..
	208	..	”	Djabrailove,	..	3	..
	209	..	"Moskou,"	Tagieve,	12,510	7	87,370
	210	..	"Mubarek Abad,"	Ter Verdieve,	13,400	3	40,200
	211	..	”	Chudaverdieve,	12,833	5	64,165
	212	..	”	..	..	2	..
	213	..	"Muctar Abad,"	Achmed Gasan,	23,444	7	164.108
	214	..	"Nadiejda,"	Kulikove,	15,970	2	39,140
	215	..	”	..	..	3	..
	216	..	"Nadjave Abad,"	Dadasheve,	18,954	7	132,678
	217	..	"Nasliednik,"	Varlamove,	36,212	7	253,484
	218	..	"St. Nicholas,"	..	12,750	2	25,500
	219	..	”	Zaitseve,	6,745	4	26,980
	220	..	”	Zeinalove,	..	3	..
	221	..	"Paraskovia,"	G. Mamedove,	5,224	2	10,448
	222	..	"Pervenetz,"	Ashumove,	21,800	7	152,600
	223	..	"Persianin,"	..	..	2	..
	224	..	"Peter Veliki,"	Semienove,	15,380	4	61,520
	225	..	"Peter I.,"	Kulikove,	41,436	9	372,924
	226	..	"Pojarsky,"	Kononove,	15,380	4	61,520
	227	..	"Pravoslavni,"	Pichtin,	21,576	9	195,184
	228	..	"Rachim Abad,"	Sadikor & Co.,	17,938	6	107,628
	229	..	"Rsa Abad,"	Ogly,	..	6	..
	230	..	"Russia,"	Tsherviakove,	6,631	2	13,262
	231	..	"Sabunchi,"	N. Achmudove,	34,468	6	206,808
	232	..	"Samarkand,"	Shakurove,	34,298	4	137,192
	233	..	"Sam Ashroff,"	Ashurove,	7,494	3	22,482
	234	..	"Sam Dadash,"	Babasheve,	13,348	4	53,392
	235	..	"Sam Tagi,"	Aleskerove,	11,954	5	59,770
	236	..	"Sam Talib,"	G. Kiaz Ogli,	16,715	6	100,590
	237	..	"Sam Salam,"	Zainalove,	17,290	5	86,450
	238	..	"Safontseve,"	Safontseve,	33,223	7	232,561
	239	..	"Sevastopol,"	Vorobieff,	15,355	6	92,130
	240	..	"Sereja,"	..	..	1	..
	241	..	"Sophia,"	Kulikove,	35,151	10	351,510
	242	..	”	Jacubove,	15.020	1	15,020
	243	..	”	Pichtin,	..	4	..
	244	..	"Sasheb Zoigam,"	Bagirove,	27,137	6	162,722
	245	..	"Stambul,"	Ibragimove,	11,129	6	66,774
	246	..	”	Marieve,	11,129	2	22,258
	247	..	"Suvorove,"	Senukove,	14,010	3	42,030
	248	..	"Soleiman,"	Zeinalove,	13,122	9	118,098
	249	..	"North East,"	Dadasheve,	15,453	8	123,627
	250	..	"Tamara,"	Kar & Popove,	23,478	10	234,780
	251	..	"Transport,"	Kalesnikoff,	18,559	7	129,913
	252	..	"Three Brata,"	Gubinin,	8,047	5	40,235
	253	..	”	Shuliesheff,	8,077	4	32,308
	254	..	"Usein Abad,"	Bakichanove,	4,183	2	8,366
	255	..	"Useinie,"	Guseinove,	17,506	8	52,518
	256	..	”	Bakichanove,	8,712	3	26,136
	257	..	”	Guseinove,	18,508	8	148,064
	258	..	"Theodor,"	Bajanove,	15,586	6	93,516
	259	..	"Theradge,"	Abdulaeve,	15,146	4	60,584
	260	..	"Cheir Abad,"	..	..	3	..
	261	..	"Shichin Shach,"	..	..	5	..
	262	..	"Erivan,"	Achundove,	15,802	7	110,614
	263	..	"Eidari,"	Gulieve,	21,667	6	130,002
	264	..	"South West,"	Dadasheve,	16,030	8	128,240
				Grand total,	5,469,816	3715	

Years of Construction.	Number of Steamers.	Capacity of the Steamers in cubic feet.	Number of Sailing Vessels.	Capacity of the Sailing Vessels in cubic feet.	Total Capacity of Steamers and Sailing Vessels in cubic feet.
1877, . .	..	..	2	19,705	19,705
1878, . .	1	15,610	15	170,577	186,187
1879, . .	1	22,050	13	135,513	157,563
1880, . .	2	58,885	2	18,383	77,268
1881, . .	5	147,484	12	177,358	324,842
1882, . .	6	182,616	18	272,188	454,804
1883, . .	4	106,182	4	159,378	165,560
1884, . .	2	40,520	3	44,477	84,997
1885, . .	2	44,058	3	37,276	81,334
1886, . .	2	60,628	10	144,939	205,567
1887, .	3	67,384	14	203,961	271,345
1888, . .	8	220,451	23	433,894	654,435
1889, . .	5	163,755	20	405,995	569,750
1890, . .	9	283,245	8	186,604	469,849
1891, . .	4	162,931	3	81,186	244,117
..	2	38,827	90	1,863,667	1,902,494
	56	1,614,653	240	3,855,163	5,469,817
	1	..	24	..	..
	57	1,614,653	264	3,855,163	5,469,817

APPENDIX C.

IMPORT DUTIES LEVIED ON PETROLEUM.

AUSTRALASIA.

New South Wales (1892).

Naphtha and gasoline,	6d. per gallon.
Other oils,	6d. ,,

Queensland.

Axle and lubricating grease,	6s. per cwt.
Asphalt,	15 per cent. *ad valorem.*
Kerosene and mineral oils generally,	6d. per gallon.

South Australia (1887).

Kerosene,	3d. ,,
Naphtha, oils, turpentine, and varnish,	6d. ,,

Victoria (1890).

Oils in bulk (except refined mineral oils flashing below 80° F., kerosene, and lubricating oils chiefly composed of mineral oil, which are admitted free),	6d. ,,

Note.—The Board appointed to consider the question of a modification of the existing tariff, has reported during the current year (1895) in favour of reducing the above duty to 3d. per gallon.

West Australia (1888).

Mineral oils and turpentine,	6d. ,,

Tasmania (1875).

Kerosene and gasoline,	6d. ,,

New Zealand.

Mineral oils,	6d. ,,

AUSTRIA.

		Per 100 kilos.
Crude oil unfit for lighting or lubricating unless refined,	Sp. gr. above 0·830 at 12° R.	2 florins.
	,, 0·830 or less,	2·40 ,,
Crude oil fit for lighting, &c., without further refining (including consumption duty),		10 ,,
Refined or semi-refined. Dark oils above 0·880 sp. gr., and residues,		3 ,,
Yellow and reddish-yellow oils above 0·880 sp. gr., including lubricating oils and mixtures with animal or vegetable fats or oils,		5 ,,
Light oils of 0·880 sp. gr. or less,		10 ,,
Refined oils of sp. gr. below 0·770, for industrial purposes other than lubricating or lighting, and under special conditions,		3 ,,

BARBADOS (1891).

Petroleum and its products, crude and refined, . .	1⅞d. per gallon.

BELGIUM.

Mineral oils are admitted free.

BRITISH BURMA—see India.

BRITISH GUIANA.

The Customs Act of 1865 imposed a duty on oils giving off an inflammable vapour below 130° F. of . .	$3 per gallon.

Note.—The Governor in an ordinance, dated December, 1881, authorised the admission of oils testing 110° F., at 15 cents per gallon, *in cash*, and 285 cents *by note;* the latter to be only collected in the event of the Combined Court refusing to refund such amount of duty.

Present duty (1892)—Standard test oil, ...	18½ cents per gallon.
Gasoline (only admitted under special permit), . .	25 ,, ,,
All other low-test oils, ...	$3 ,,
Except those from the United States, which, by treaty arrangement, pay only	$2·25 ,,

CANADA (1894).

Illuminating oils, composed wholly or in part of the products of petroleum, coal, shale, and lignite, costing more than 30 cents per gallon, ...	25 per cent. *ad valorem.*
Oils (coal) and kerosene, distilled, purified, or refined; naphtha and petroleum not elsewhere specified; products of petroleum not elsewhere specified, . .	7⅕ cents per imp. gall.
Lubricating oils, composed wholly or in part of petroleum and costing less than 25 cents per imperial gallon, .	6 cents ,,
Crude petroleum, fuel and gas oil for fuel purposes, and for the manufacture of gas, ...	$3\frac{3}{16}$ cents ,,
Lubricating oils, not elsewhere specified, and axle grease,	25 per cent. *ad valorem.*
Barrels containing petroleum or its products, or any mixture of which petroleum forms a part, when such contents are chargeable with a specific duty, . .	20 cents each.
Paraffin wax, ...	2 cents per lb.
Paraffin wax candles, ...	4 ,, ,,
Vaseline and all similar preparations of petroleum for toilet, medicinal, or other purposes, ...	35 per cent. *ad valorem.*

CAPE COLONY (1889).

Paraffin and raw and boiled linseed oils, ...	3d. per gallon.
All other descriptions of oil (except chemical, essential, or perfumed), ...	1s. ,,

CHILI.

The duty on kerosene is equivalent to about . . .	3s. 2d. per case.

CHINA.

At Shanghai, the import duty is . . . . . . and the same rate is believed to be in force at other ports.	5 per cent. *ad valorem.*

CUBA.

Crude oil,	$4\frac{1}{4}$ cents gold per gall.
Refined oil,	$29\frac{25}{100}$,, ,, ,,

In addition, there is an internal revenue tax of $7\frac{31}{100}$ cents per gallon on refined oil, whether produced in the country or imported.

DENMARK.

2 ore per pund.

(The ore = $\frac{2}{15}$ of a penny. The pund = 1·1 lbs. avoirdupois.)

FRANCE.

	General Tariff per 100 kilos.	Minimum Tariff per 100 kilos.
Bitumen,	Free.	Free.
Crude ozokerite,	12 francs.	10 francs.
Refined ,,	50 ,,	40 ,,
Crude petroleum and mineral burning oils,	18 ,,	...
Refined ,, ,, ,, ,, and essences,	25 ,,	...
Heavy oils and residues,	12 ,,	12 ,,
Paraffin,	35 ,,	30 ,,
Vaseline,	32 ,,	28 ,,

GERMANY.

Mineral oil for industrial purposes or refining, but not for the manufacture of lighting or lubricating oil,	Free.
Mineral lubricating oils,	10 marks per 100 kilos.
All other kinds,	6 ,, ,,

GREECE.

The import of petroleum oil is prohibited, the sale being a Government monopoly.

All other mineral oils pay duty equal to about	16s. 6d. per cwt.

HOLLAND.

55 cents (Dutch) per 100 kilos.

HONG KONG.

Mineral oils are admitted free.

INDIA.

Petroleum, including also naphtha and the liquids commonly known by the names of rock oil, Rangoon oil, Burma oil, kerosene, paraffin oil, mineral oil, petroleine, gasoline, benzol, benzoline, benzine, and any inflammable liquid which is made from petroleum, coal, schist, shale, peat, or any other bituminous substance, or from any products of petroleum,	1 anna per imp. gall.
Petroleum which has its flashing point at or above 200° of Fahrenheit's thermometer, and is proved to the satisfaction of the collector of Customs to be intended for use exclusively for the batching of jute or other fibre, or for lubricating purposes,	5 per cent. *ad valorem*.

Italy.

Heavy oils imported in bulk,	9·60 lire per 100 kilos.
Other oils imported in demijohns and similar vessels,	51 ,, ,,
,, ,, other receptacles,	48 ,, ,,

Jamaica.

Petroleum and its products, crude or refined,	9d. per imp. gallon.

Japan.

The duty is on the f.o.b. cost, the value of the *package* being also included in the estimate.	5 per cent. *ad valorem*,

Malta.

Mineral oils are admitted free.

Natal.

Refined oil,	6d. per imp. gallon.

Newfoundland.

Refined oil,	5 cents per gallon.

Note.—In 1892, an additional duty of 5 cents per gallon became leviable on kerosene from all countries allowed to fish for cod on the Newfoundland coast, in case they or their dependencies shall levy any duty on the fish or the produce of the fisheries from Newfoundland or its dependencies.

New Zealand—see Australasia.

Norway.

Mineral oils are admitted free.

Peru.

Kerosene,	2¾ soles (or dollars) per case.

Portugal.

Light illuminating oils,	67 reis per kilo.
Intermediate oils, sp. gr. between 0·820 and 0·860,	60 ,, ,,
Heavy oils for lubricating,	2 ,, ,,

Roumania.

Crude oil,	20 francs per 100 kilos.
Refined oil,	15 ,, ,,

Russia.

Refined oil,	1 rouble per pood.
Crude oil,	20 kopecks ,,

SPAIN.

	Maximum Tariff per 100 kilos.	Minimum Tariff per 100 kilos.
Pitch, tar, asphalt, bitumen, and shale (gross weight),	0·60 peseta.	0·40 peseta.
Oleonaphtha, vaseline, natural crude petroleum, and crude oils from shale, ...	25 ,,	25 ,,
Petroleum, crude and refined, pays an additional duty, ...	0·50 ,,	0·50 ,,
Benzine, gasoline, petroleum, and other refined mineral oils, ...	40 ,,	40 ,,
N.B.—Duty is levied on the nett weight of petroleum, but on the gross weight of the other substances mentioned.[1]		
Paraffin, stearine, animal fats, and sperm, . .	24 ,,	20 ,,

Crude shale oil is described as the oil from the first distillation of shale, recognisable by its yellowish colour and specific gravity (0·900 to 0·920) or measuring 66 per cent. to 57⅓ per cent. by the centesimal areometer (= 24·69° to 21·48° Cartier).

Natural crude petroleum is stated to be, either such as when distilled at 300° C. in a glass vessel, leaves a residue exceeding 20 per cent., which residue in turn yields at least 1 per cent. of coke (both calculated on the original weight of oil), or such oils as flash below 16° C. in the Granier cup. All other mineral oils are classed as refined.

STRAITS SETTLEMENTS.

Mineral oils are admitted free.

SWEDEN.

Mineral oils are admitted free.

SWITZERLAND.

Uniform duty of 1·25 francs per 100 kilos.

TASMANIA—see Australasia.

TURKEY.

80 per cent. *ad valorem*.

UNITED STATES.

"Petroleum, crude or refined, ...	Free.
Provided that, if there be imported into the United States crude petroleum or the products of crude petroleum produced in any country which imposes a duty on petroleum or its products exported from the United States, there shall be levied, paid and collected, upon said crude petroleum or its products so imported, 40 per centum *ad valorem* . . ."	

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[1] The package pays duty separately, according to its classification—barrels, 13 and 10 pesetas; tins, 60 and 50 pesetas; and cases, 31·20 and 24 pesetas, maximum and minimum rates respectively per 100 kilos.

ADDENDA.

Historical.—In the *Oil, Paint, and Drug Reporter* (New York), of 22nd July, 1895, Mr. A. C. Ferris points out that, whereas the official statistics of the production of petroleum in the United States begin with the year 1859, there was a considerable amount of business transacted in petroleum for use as an illuminant during the two previous years.

Production.—In the *American Manufacturer* of 3rd May, 1895, Mr. Weeks describes a new single-eccentric drilling engine, manufactured by the Oil Well Supply Company, under the Woolf patents of 30th July, 1889, and January 13th, 1891, which is claimed to possess unusual simplicity, economy, and effectiveness. This engine having only one eccentric and rod, there is no link to get out of order. The single eccentric is rigidly secured to the shaft, and the eccentric strap has an upward arm, on the end of which is pivoted a roller which travels in a guide journaled in a bracket on the engine frame. The eccentric has its centre opposite the crank pin, and when the engine is on either dead centre, the roller stands exactly over the centre of the guide. The correct position for the eccentric is thus easily determined, and the length of the eccentric-rod is then adjusted so as to give equal "lead" at both ends of the valve. The valve is thus set, and requires no further adjustment. The direction of the motion is regulated by the guide which moves the eccentric strap. By the lever attached to the guide, its inclination can be changed, either to vary the travel of the valve, and thus regulate the point of "cut-off," or to reverse the engine.

These engines have been tested in actual work at oil wells, and are stated to have afforded very satisfactory results.

Refining.—Among the most notable recent achievements, has been the solution of the problem of refining Lima (Ohio) petroleum. It is well known that much of the oil found in Ohio and Indiana contains a considerable percentage of sulphur compounds, and the earlier attempts to eliminate these impurities were attended with so little success that, under the rules of the New York Produce Exchange, "refined petroleum made from the crude oil of the district known as Lima, or oil made from crude oil of similar quality," could not, until quite lately, be delivered on contracts. The refining of Lima oil is now, however, so successfully conducted, that there is no longer considered to be any practical difference between the product and that obtained from Pennsylvania oil. The rules of the New York Produce Exchange have accordingly been so amended as to admit of refined oil from Lima petroleum being delivered on contracts. In proof of the estimation in which this product is held, it may be mentioned that at least 60 per cent. of the kerosene consumed in the United States during the year 1894, was manufactured from Lima oil, and it is anticipated that the proportion will be still larger for the current year. It is interesting to learn that concurrently with the improvements which have been effected in the purification of the oil, there has been a steadily progressive increase in the proportion of kerosene obtained from the crude oil. Apart, therefore, from the greater cost necessarily attending the refining of Lima oil, which causes this description of crude oil to have a lower commercial value, the difficulties which have hitherto attended the utilisation of the produce of the Ohio and Indiana oil fields. as a source of illuminating oil, may be considered to have been completely overcome, and in view of the highly productive character of these territories, it may fairly be said that no other advance in the chemical technology of petroleum has been of similar industrial importance.

Transport.—The new tank barges employed by the Standard Oil Company in the shipment of crude oil from Whiting, Ind., are described in the *American Manufacturer* of 2nd August, 1895, as steel schooners, with three masts, carrying a good spread of sail. They are 170 feet long, 33 feet beam, and 17 feet deep, and they carry 8,000 barrels of oil in the eight compartments, four on each side, into which the vessels are divided. The masts are hollow, and the foremast is utilised as a smoke stack. The boiler supplies steam for cargo pumps, capstan, windlasses, and electric light.

INDEX.

The impossibility of providing a complete detailed index to this work within reasonable limits has necessitated the abbreviation of most of the references, and the exclusion of some, although such omissions have been avoided as far as possible. In the case, for instance, of several of the oil fields, the reference has been shortened to the name, followed by a comma, and the word oil. Thus, such an entry as:—"Bemè, oil," relates not only to the oil itself, but also to its occurrence, the geology of the district, and the development of the oil field. The principal headings, such as Petroleum, Production, Statistics, and the names of the more important oil fields, have been but little amplified, as the various sub-divisions will be found indexed under their respective headings. The Table of Contents, which fully indicates the scope and arrangement of the work, will furnish considerable assistance to the searcher.

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